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Become a ChatGPT master!

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REVIEWS

Acer's 3D gaming laptop
Glasses-free 3D gaming & modelling

HP's NEW luggable
The 24in all-in-one with a battery!

HIGHLIGHTS THIS MONTH

Full contents overleaf

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HP Envy Move

If you've always had a secret affection for 1980s' luggable PCs, then you're in luck: so does HP. It has reinvented the idea with this 24in all-in-one PC that also happens to include a battery, which means that you can indeed use it anywhere. It's a distance lighter than the Osborne 1, at 4kg rather than 11kg, and a world away in terms of power. The 1440p screen is ever-so-slightly superior, too. To find out exactly how fast it is, and what sort of battery life you can expect away from the mains, turn to p46.

p26

SUPER POWER OF THE MONTH

We get that AI has been hyped up to the max, but there are genuine, practical ways that you can put it to work right now. Barry Collins explains how from p26.
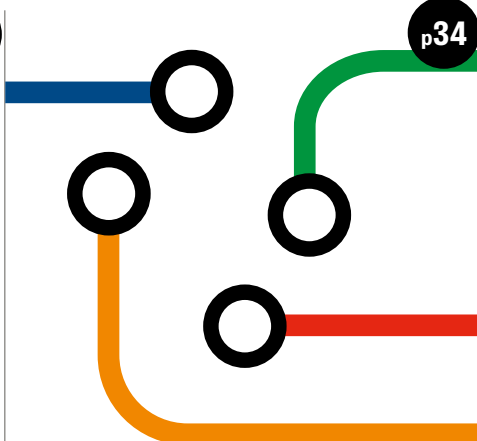
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DATA POWER OF THE MONTH

Is it possible to be scared and impressed at the same time? That's how we felt on discovering how Transport for London was using mobile phone data to keep the Tube working smoothly.

p38

ONE THING YOU SHOULD DO THIS MONTH

Backups are one of the dullest things ever - until something awful happens and you realise that the data you keep on your PC, laptop and phone could be at risk. Here's how to do the right thing.

p123

COMPUTER OF THE MONTH

Apple Macintosh

Some might argue that the Apple Macintosh was the computer of the century, but it will have to make do with being our pick of the month as we mark its 40th birthday with a special article.

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THE LABS IN ONE NUMBER

Still paying a small fortune per printed page? If so, we humbly suggest you head to our group test of printers on p78. There, you'll find a selection of lasers and inkjets designed to produce great-quality prints for as little as 0.1p per page.

0.1p

p38 **HASSLE-FREE BACKUP FOR WINDOWS, MACS & PHONES**

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Yes, the Scan 3XS GWP TR Ada costs £17,000 inc VAT, but this graphics workstation is worth every penny

PRINTERS
THAT LAST

Don't buy a cheap throwaway printer that ends up in landfill after a year and costs a fortune to run. We review 14 contenders that make more long-term sense.

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94 **Wi-Fi 6 & 6E access points**
Forget Wi-Fi 7 for now, says Dave Mitchell. Wi-Fi 6 and 6E points designed for business use will be your best bet for years to come.

RETRO

123 **40 years of the Mac**
Released in 1984, the Apple Macintosh soon became an iconic machine, starting a range that continues to this day. David Crookes looks at how that first computer came to be.

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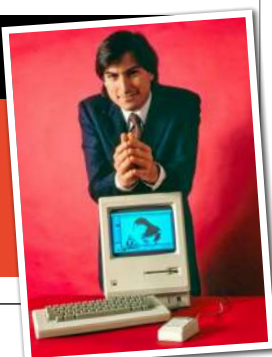**126** **Quantum computing is here...**
...with one small caveat. Nicole Kobie meets a company mitigating the effects of climate change to find out why the government is backing 30 projects to kickstart quantum tech, even though the hardware isn't ready.

When it comes to AI, we've all got a lot to learn

There comes a time when everyone hits an intellectual ceiling. For me, it happened at university. I adored Maths as a child, flying through early years, secondary school and A-levels. So it seemed a natural choice for university, only for me to discover that my brain fell far below those of my brightest colleagues when it came to this new, abstract world. I lost count of the times our Geometry professor scrawled a heap of symbols on the huge whiteboard before muttering "the proof is obvious" and wandering off stage right.

Ever since, I've been determined to persevere even if the going gets tough. Especially when it comes to new technology: I want to embrace it, understand it, get under its skin. I'm not trying to be an industry expert, merely to grasp the principles enough that I can both take advantage of each development and have reasonable conversations with those who *are* industry experts.

Like so many others, when ChatGPT burst onto the scene in November 2022 I realised this was another one of those moments. I could ignore it, pretend it didn't exist, or try to understand it. In short, I could be one of those people who say "Oh, I don't get AI" in the same way that many people said back in the 1980s, "Oh, I don't get computers". So I tried to understand it. I signed up for new, free services whenever they appeared, paid a few pounds per month for one that I thought might help me in my work (it didn't), and told myself I was embracing AI.

But the truth is, I wasn't. Sure, I knew more than the average Clapham omnibus traveller, but my knowledge was skin deep. So I decided, a couple of months ago, that I wasn't going to let this technology slide past me. My first step was to attend an IBM briefing about how it's using AI, with one example being how it was turning unstructured data – reports of new building applications in a Norwegian city – into actionable information that local investigative journalists could follow up and report on.

It was this quest to educate myself – along with an Airbus A380 – that took me to San Jose, California, at the start of December for AMD's Advancing AI conference. Well, "conference" oversells it. This was a launch event for AMD's Instinct MI300 AI accelerators, its latest (and almost certain to be successful) attempt to muscle market share away from Nvidia in the world of high-performance computing.

The impressive Dr Lisa Su, AMD's CEO, held up a sample of the Instinct on stage, and although I couldn't see the silicon due to the whopping heatsink, I couldn't help but be impressed by the sheer brute force power that lies beneath. Each accelerator contains 153 billion transistors with 228 GPU compute units and 128GB of HBM3 memory. And there are eight accelerators per board. At some point, much like many of my lectures, the numbers become meaningless.

I wasn't just there for the hardware. I chatted to analysts and experts about AI. I admired some of the demos, including an implementation of Meta's Llama 2 that runs on AMD's Ryzen AI chips (built into its 7040 series and the 8040 series that was also announced at the event). I felt, by the end, that I was starting to understand the AI ecosystem. Perhaps I couldn't complete a proof on a giant blackboard, but I was edging closer.

Yet, hurdles remain. You see, I still don't understand how Barry turns photos of me and my fellow podcasters into amazing images in the style of Pixar, Lego and *Grand Theft Auto*. I haven't yet created my own GPT. And nor have I signed up to ChatGPT Plus so that I can use the advanced tools Barry extols. That's why, if you turn to our feature on p26 and follow his advice, you won't be alone. Somewhere, probably scratching my head, I'll be trying to get to grips with it, too.

Tim Danton
Editor-in-chief

CONTRIBUTORS

James Morris
On finishing his review of the latest Scan workstation, James emailed us to say, "This system is insane. My own 32-core system is now cowering with insecurity in its presence." Find out why on **p52**.

James O'Malley
Through a handful of freedom of information requests, James managed to find out exactly how Transport for London is using our mobile phone data. Be impressed, if a little scared, by turning to **p34**.

Olivia Whitcroft
We know what you're thinking: there isn't enough *Quantum Leap* in this magazine. Fortunately, Olivia sets out to right this wrong as she explains the legal ramifications of using AI on **p116**.

Simon Handby
If there's one person that knows about printers, it's Simon. This month, he puts 14 inkjets and lasers to the test, to find out which wins for speed, quality and the all-important running costs, from **p78**.

Our main feature this month (see p26) covers ChatGPT and how to create your own GPTs – that is, personalised AI assistants. On p25 we find out what our readers would love personal AIs to do for them, but what about our contributors?

"I'm greedy. I don't want one, I want a dozen. But let's start off with an AI to automatically generate a to-do list for me each day, another that kicks in whenever I start a task to offer help and a third to make me healthier and happier. I did mention I was greedy…"

"I'd like an AI assistant to catalogue all my photographs, indexed by date, location, camera used and people in pic."

"Answer these incessant Masthead questions for me."

"Tag and categorise the gazillions of photos I've got cluttering SSDs and cloud storage, please."

"Automated ironing. What a pointless exercise."

"I'm tempted to say it could do my work for me, but if someone did actually perfect an AI that can design I'd be out of a job!"

"Pretend to be me answering the voice calls I now get on my smartphone. 90%+ are scammers: the rest are dim-bulb chaser-upper types who think I won't need validation that they are who they say they are. A nice world-weary, cynical Alexa-type device burbling nonsense at unrecognised callers would be perfect."

"I yearn for an AI-powered machine to sort two decades of varied PC screws into trays."

"Curate all of my connections to social media, web, email and put it under my control. Basically, filter out all the spam and c**p."

"Read and summarise daily legal updates, then pick out the most interesting and relevant stories for me."

"Post context-aware content across the fragmented social media space with one click."

The civil war at OpenAI

The sacking and rehiring of its CEO exposes internal strife at the world's best-known AI company

Last year almost couldn't have gone any better for Sam Altman, the 38-year-old CEO of OpenAI. Except for one very strange weekend in November.

It was almost exactly a year after the launch of the company's world-changing new AI product, ChatGPT, and the company was riding high. It was valued at almost $90bn following a $10bn investment from Microsoft. From almost nowhere, it had become one of the world's most important tech companies.

But then on the Friday before Thanksgiving in the US, the company dropped a bombshell: Altman had been fired. In a short press release, the OpenAI board said that Altman had not been "consistently candid in his communications" – a phrase that kicked off a weekend of intense speculation about what the problem could be.

One hypothesis was that Altman was seeking finance from the Middle East to work with Nvidia to design custom AI chips – a move that OpenAI co-founder and chief scientist Ilya Sutskever reportedly opposed. But it eventually transpired that the trigger was more of a philosophical debate, stemming from OpenAI's dual identities.

"I think what was happening was the board [got] out of its own depth," said Anthony Quigley, founder and executive chairman of the Corporate Governance Institute.

He describes how OpenAI is, unusually for Big Tech, structured as a not-for-profit organisation. Not even Altman owns any equity in the company. Instead, the board was composed of a mixture of business figures and technologists linked to the "Effective Altruism" movement, who are concerned with

> **It appears the board were unnerved by the pace of innovation in the company**

the company's original mission of developing AI safely.

Warring factions

What appears to have occurred is a clash of visions: Altman's "tribe", as he described the two warring factions, was the company's commercial arm. And it appears the board, which takes a broader and less utopian view of AI, were unnerved by the pace of innovation in the company. Altman's drive to launch new AI products – such as GPTs (*see p26*) designed to provide ChatGPT-like functionality for specific use cases – appears to have been the last straw.

"If I was on the board, I wouldn't want OpenAI to be those guys who unleashed a product or service to the world that

caused huge damage and [could] upset a whole country or a whole cohort of people," said Quigley.

Despite the fact the company is expecting to earn a billion dollars this year, it appears the non-profit "tribe" on the board started growing nervous and decided to act. "The way a not-for-profit board works is completely different from the way a for-profit board works," said Quigley.

"Not-for-profits think about goodness, society, the power of good, and how do we affect change that will enhance humanity. A for-profit board thinks about how we are going to benefit the shareholders who have invested in us."

He thinks the breakdown was partially due to this whiplash from the company's rapid rise to become such a valuable entity – you might typically expect a company of that size to be structured more like Apple, Microsoft or Meta.

"A board was put together with really clever, smart people, but they were clever, smart people with a different mindset, different expertise than was required for this board," said Quigley. "Suddenly they went from not-for-profit to having money beyond our imagination."

> **" Suddenly they went from not-for-profit to having money beyond our imagination "**

In any case, the boardroom coup ended almost as dramatically as it started. Shortly after Altman was ousted, Microsoft CEO Satya Nadella announced that Altman and OpenAI's CTO, Greg Brockman, would be joining the Redmond firm along with several of their colleagues, to lead a new, home-grown AI division. Helpfully, as part of its big money investment, OpenAI gave Microsoft a blanket licence to use its AI models, so Altman would be able to continue his work unimpeded.

However, Altman never got the chance to get his feet under his new desk at Microsoft. When the news broke, a huge employee revolt kicked off at OpenAI, with 745 of the company's 770 staff signing a letter, threatening to resign en masse and follow Altman to Microsoft – unless the remaining board resigned, too.

With their hands tied, a "peace deal" was reportedly brokered by Nadella – and just three days after the entire affair began, on 20 November, it was announced that Altman and his colleagues would be returning to OpenAI, with Altman reinstated as CEO – the commercial "tribe" apparently victorious, and one of the most important companies in the world seemingly back on its feet.

Firefox edges closer to being put down

Mozilla's browser looks set to drop below a critical user threshold

If you had asked any techie in 2007 what the single most important thing you could do to upgrade your browsing experience was, chances are they would have said "download Firefox".

Mozilla's open-source web browser was a revelation back in the day. It loaded quickly, it didn't consume your system memory, and its rendering engine obeyed commonly agreed web standards, making it easy to develop for. It was everything Internet Explorer wasn't.

Firefox was hugely successful, with around 31% of all web browser usage in 2009, according to StatCounter. But fast-forward to 2023, and into a mobile-first world dominated by Chrome, Edge and Safari, the future of Firefox is more uncertain than ever – the browser now accounts for only 2.2% of users.

This puts Firefox in a precarious position. The tech blogger Bryce Wray recently noted that its declining market share puts Firefox dangerously close to a cut-off that is built into the design guidelines of US and UK government websites. Simply put, according to the US Web Design System, government sites must be designed to work on browsers with a market share of more than 2% – so priority is given to building sites that work on Chrome, Safari and Edge.

Once it falls below that water line, Wray speculates that this could lead to a cascading effect, as important websites will no longer necessarily work correctly with Firefox. The US government will be sending a signal to other cost-conscious services and corporations that Firefox compatibility should no longer be considered essential.

The problem could be exacerbated by Firefox's rendering engine. Whereas Chrome and Edge both use Chromium, Firefox uses its own engine, called Gecko – making future compatibility an even tougher ask for developers.

However, all may not yet be lost. In public at least, Mozilla remains upbeat about the future of the browser. Writing in the annual "State of Mozilla" report, Mozilla president Mark Surman said: "Mozilla's core capabilities have always included a mix of being able to shape the market with responsible tech products and being able to gather a movement of people building and advocating for a better internet."

To give an example of this, he points to the planned introduction of a new "FakeSpot" feature that helps Firefox users detect fabricated reviews on shopping sites, deploying AI and machine learning to identify reviews with eerily similar characteristics, or that carry other hallmarks of inauthenticity.

Surman also spoke of how Mozilla is hard at work on an open-source large language model for AI use, writing: "These tools serve as building blocks that are needed to ensure a competitive market and allow developers to build trustworthy AI products at scale. If successful, this work will shape how the market develops, creating a more open and competitive AI ecosystem."

Mozilla also still has a very active product roadmap, having announced plans for new software releases on a monthly basis, running all the way through to February 2025.

So perhaps Firefox isn't dead quite yet.

The famous fox has almost been hunted to extinction, but there are still signs of life in the organisation

PC Probe

Why did Apple surrender on RCS?

Apple's tight grip on iPhone messaging has weakened with support for RCS. James O'Malley investigates why the company relented

When it comes to upgrading a phone, it's not always easy to switch camps. Sure, the new Samsung or Google Pixel may be tempting, but if you're already an iPhone owner, sticking with Apple is the path of least resistance.

That's not only because Apple makes migration between its own devices easier, but because it has worked hard over the years to lock users into its ecosystem. For example, if you make the switch you may need to pay again to download on Android the premium apps and games you bought long ago on iPhone. And what about the Apple Watch? If you break up with Apple, you've got yourself an expensive paperweight wrapped around your wrist.

But perhaps Apple's most powerful lock-in trick is something less tangible: that blue bubble in the Messages app, which denotes the sending of not merely a text message, but an iMessage. When two iPhone users text, they can take advantage of many richer features, such as higher-quality photos, read receipts and dots that show your friend is typing.

For several years now, most Android users have enjoyed something similar, in the form of RCS, the Rich Communication Standard. But since the dawn of the smartphone era, iPhone-to-Android messaging or vice versa has been restricted to 160-character SMS. Apple has always made it clear that it considers Android users second-class citizens, relegating them to lowly green speech bubbles, instead of the more elite blue.

Now the iron curtain between the two smartphone empires is about to fall. After years of complaints from Google, Apple has announced that it is finally relenting. Next year, the company will roll out an update bringing RCS support to iPhone – heralding a new era of rich cross-platform texting.

Why has Apple caved in? And what does RCS-for-all actually mean for smartphone owners?

■ Breaking barriers

"I think it's genuinely transformational," said James O'Hare, managing director of LINK Mobility UK, a firm that provides messaging services to business customers.

iMessage… on Android?

In parallel with Google's lobbying efforts, developers and hackers have long been attempting to reverse-engineer Apple's proprietary iMessage software so messages could be sent and received on Android devices. So far, the story has been a mixed success.

The highest-profile example of a workaround has been Sunbird, a company that last year partnered with Nothing, a new phone company owned by OnePlus co-founder Carl Pei, to launch a messaging app called Nothing Chats. The launch got a huge amount of attention, because the developers promised it would give Android users the all-important blue bubble when messaging iPhone-owning friends.

On a technical level, it involved a convoluted workaround. Sunbird was thought to be using Mac computers in the cloud to bridge the connection between iMessage and the Android messaging app – essentially logging users into that cloud computer with their Apple account credentials and forwarding messages back and forth.

However, despite promises of advanced security features such as end-to-end encryption, the launch quickly fell apart as security experts discovered that messages sent by users were being stored unencrypted in the cloud. As a result, the app was pulled from the Google Play Store and the developers have been sent back to the drawing board.

But there may still be a ray of hope for Android users. Weeks after the Sunbird debacle, a rival firm called Beeper launched its own app. Its service also used a Sunbird-like middle-man model, but has since moved on to Beeper Mini, which appears to be a fully reverse-engineered iMessage protocol that handles all of the account authentication and message transportation locally on the device.

This means that no personal data is sent to the cloud, and messages are exchanged directly with Apple's iMessage servers by tricking Apple's servers into thinking the Android phone in your hand is, in fact, an iPhone.

Whether the service will endure remains to be seen – Apple could conceivably re-engineer its systems to close the Beeper loophole. Were that to happen, however, you should soon be able to rely on RCS instead.

services" – essentially Apple, Microsoft, Meta and Google – to ensure that messaging apps are interoperable. And because Europe is such an important market, it's likely that the same functionality will be rolled out worldwide. The RCS announcement could simply be Apple grudgingly doing what it will soon be obliged to do by law anyway.

Good for business

Whatever the motivation, Apple's embrace of RCS marks a significant moment, although it may not be chatty

He's excited by the possibilities of Apple adopting the "universal profile" of RCS – the name for the shared set of standards that the rest of the mobile industry has agreed to facilitate richer communications.

"What this universal profile does is it creates the ability for those innovations to cross operating systems," said O'Hare. "So you can have the images, the GIFs, the reactions, the groups, and you can actually have those across both operating systems. You could have a group with both Android and iPhone users and the experience will be exactly the same."

Under the hood, RCS is much better suited to life in 2024. Traditional SMS is sent using spare bandwidth in the spectrum that carries 2G voice calls (hence why it takes a few seconds to send an SMS), but RCS operates via a data connection and will even work over Wi-Fi. It still needs the phone networks to broker the messages, who will have to choose to support it – although all of the major UK networks do (in a similar manner to Wi-Fi calling).

Apple cornered

Still, Apple already offered all of these features to its iPhone owners. So why has it decided to break its exclusive club? One reason might simply be the competition.

O'Hare believes that universal messaging rivals such as WhatsApp may have played a part in the decision. WhatsApp is operating-system-agnostic and "can create innovative solutions for messaging, regardless of whether it's an Apple or an Android," he said.

In many markets, including the UK, iMessage and traditional SMS are simply not all that popular. According to a recent study by Ofcom, the telecoms regulator, 76% of British adults said they use WhatsApp, compared with only 20% using iMessage.

One other explanation could be the emergence of Android tools such as Beeper, which have broken open the iMessage protocol, meaning that Android devices could soon be using iMessage by the backdoor anyway (*see box*).

But perhaps the most important reason for the change is that Apple was forced into a corner. "I think it's probably due to the EU's Digital Markets Act," said Molly Gatford, a research analyst with Juniper Research.

Coming into force next March, the new law is expected to require the big firms that provide "core platform

ABOVE Android users will soon have equal rights on iOS

consumers who benefit most. "It's not going to feel massively different, I don't think, from a consumer's perspective," said O'Hare. "I think where the huge difference will be felt is in the business world."

He describes a future where doctors' appointment reminders and delivery notifications could be delivered using RCS, making it cheaper for organisations to send messages at scale.

And not only will it spur companies to send richer messages (imagine, for example, a parcel-tracking message with an embedded map), it will also enhance security with more built-in controls for verifying the identity of senders. This means it could conceivably mean the end to SMS scams, where the sender's name has been spoofed by the operator. That alone could "almost eliminate spam phishing attempts," said O'Hare.

> **It could conceivably mean the end to SMS scams, where the sender's name has been spoofed by the operator**

However, what might prove more of a mixed blessing is universal RCS support making messaging more attractive to marketers. According to Gatford's research, once Apple activates RCS, there could be as many as 33.9% more devices (up to 6.3 billion worldwide) that use the technology – and it has long been well known that iPhone users are the most valuable users from a business perspective, because they tend to be wealthier than Android users.

"Brands are now wrestling with the idea that email marketing is declining in effectiveness, Google is phasing out cookies, so being able to actually gain new customers through display advertising is getting much harder," said O'Hare. "What marketers and what marketing agencies across the globe really are looking for is a new way of engaging customers, and I think using messaging via RCS for virtually 100% of all handsets means that you can get loads more engagement."

If Apple's announced timeline is correct, then we should see peace break out in the group chats between iPhone and Android users this year.

And of course, because Apple is Apple, there will still be one crucial difference: it will still only be iPhone users who get the elite blue bubbles.

The A-List

PC PRO ★★★★★ A-LIST

The best products on the market, as picked by our editors

PREMIUM LAPTOPS

Apple MacBook Pro 16in (2023)

M3 power from £1,699
from apple.com/uk

The M3 chips give the already brilliant MacBook Pro series a boost in games with no sacrifices elsewhere, so power users who are happy with Apple must grapple with the big decisions: which M3 chip, which size of screen, and how much RAM and storage?
REVIEW Issue 352, p46

ALTERNATIVES

Asus Zenbook S 13 OLED (UX5304)
The perfect 13in laptop? At 1kg, it packs power along with 1TB of storage, a top-quality OLED panel and superb battery life. £1,600 from uk.store.asus.com
REVIEW Issue 348, p58

Samsung Galaxy Book3 Ultra
Samsung packs everything into this 16in laptop, from a superb AMOLED panel and a slim 1.8kg chassis to a Core i9 CPU and RTX 4070 graphics. Expensive but top quality. **From £2,449 from samsung.com/uk**
REVIEW Issue 344, p46

Apple MacBook Air 15in
It's no MacBook Pro, but with an 8-core M2 chip the 15in MacBook Air offers solid performance and a spacious, good-looking display for a great price. **From £1,399 from apple.com/uk**
REVIEW Issue 347, p60

GAMING LAPTOPS

Asus ROG Zephyrus M16 (2023)
Core i9/4090 for £4,100

from rog.asus.com/uk

Asus includes everything in this gaming laptop, including a personalisable lid via a matrix of lights. And a 16in AMOLED screen, 2TB SSD and cutting-edge components. If the £4.1K price puts you off, Overclockers UK sells an RTX 4080 version with a plain lid for £3,300.
REVIEW Issue 343, p50

ALTERNATIVES   NEW ENTRY

Lenovo Legion 5i Pro (16in)
A great-value gaming laptop that's extracts the most from its powerful components. We love the keyboard, too. **Part code 82RF002LUK, £2,000 from lenovo.com/gb**
REVIEW Issue 337, p61

Lenovo Legion 9i Gen 8 (16in Intel)
The liquid-cooling system may be only for bragging rights, but this slim laptop delivers the goods with a superb 16in mini-LED screen. **RTX 4090, £4,180 inc VAT from lenovo.com**
REVIEW Issue 353, p58

Razer Blade 18
A great advert for 18in gaming laptops, the Blade 18 partners a Core i9-13950HX with RTX 40-series graphics in a stunning, slim design. **From £2,900 from razer.com/gb-en**
REVIEW Issue 343, p52

BUSINESS LAPTOPS

Lenovo ThinkPad X1 Carbon Gen 11

Business class from £1,583 exc VAT
from lenovo.com

Fight past Lenovo's opaque pricing – another flash sale, really? – and you'll find a slim, powerful and long-lasting laptop for a competitive price. With a wide range of available configurations, all based on Intel's 13th generation Core chips, this is our top choice for all sizes of business.
REVIEW Issue 350, p85

Dell Latitude 7340
This 1.1kg laptop offers terrific battery life and, if you choose the better non-touchscreen (look for 400 nits of brightness in the specs) it's a joy to use, too. **From £1,109 exc VAT from dell.co.uk**
REVIEW Issue 350, p82

Acer TravelMate P6 (TMP614-53)
The all-new TravelMate P6 benefits from a 14in OLED screen with a 2,880 x 1,800 resolution, plus a very generous spec for the price. It's simply great value. **£1,209 exc VAT from acer.co.uk**
REVIEW Issue 350, p80

HP Dragonfly G4
It's not the fastest machine you can buy, but otherwise this 1kg masterpiece is as close as you're going to get to the perfect business laptop for executives. **From £1,380 exc VAT from hp.com**
REVIEW Issue 352, p58

EVERYDAY LAPTOPS

Honor MagicBook 16 X (2023)
Full metal jacket for £700

from hihonor.com

A high-quality all-metal chassis marks the MagicBook 16 X 2023 out from the budget laptop crowd, and it's packed with good-quality (albeit not top-quality) components, from a 12th gen Core i5 chip to a 1,920 x 1,200 16in IPS panel.
REVIEW Issue 348, p59

Asus Vivobook S 15 OLED
The Core i5 version of this 1.7kg laptop offers amazing quality for under a grand, including a high-quality 15.6in OLED display. **From £949 from pcpro.link/347asus2**
REVIEW Issue 347, p85

Microsoft Surface Laptop Go 2
The Laptop Go 2 won our recent group test of affordable laptops thanks to its high-quality 12.5in screen, 1.1kg weight and sleek design. **£555 from microsoft.co.uk**
REVIEW Issue 347, p89

MSI Prestige 15
Not the most cultured laptop, but great value considering the connectivity, 15in screen, fast specs and a GeForce RTX 3050 GPU (part code A12UC-034UK). **£849 from laptopoutlet.co.uk**
REVIEW Issue 347, p93

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CHROMEBOOKS

Acer Chromebook Plus 515

Double power for £400

from currys.co.uk

An excellent debut for Google's Chromebook Plus initiative, with Intel's Core i3-1315U CPU providing the power, with 8GB of RAM and 256GB of storage for company. The chassis is well built, and the 15.6in screen is good for the price. **REVIEW Issue 351, p44**

Acer Chromebook Vero 514

Acer combines its eco-conscious Vero brand with Chrome OS to great effect in this surprisingly powerful 14in Chromebook. With a 12th generation Intel Core i5 processor, 8GB of RAM and a 256GB SSD, plus Chrome OS updates until 2030, it's a fine long-term investment that helps cut down on electronic waste. **£599 from currys.co.uk REVIEW Issue 340, p54**

HP Elite Dragonfly Chromebook

This is quite simply the best business Chromebook around, although at the time of writing we're waiting for units to hit the market. Build quality is stunning, as is this 13.5in convertible's 1.3kg weight. **From £1,000 from hp.co.uk. REVIEW Issue 337, p86**

EVERYDAY PCs

Apple Mac mini (2023)

M2 masterpiece from £649

from apple.com/uk

The outside remains the same, but this simple yet effective update to the Mac mini introduces the M2 and M2 Pro processors with predictable effect. The entry-level price quickly rises once you start upgrading – moving from 8GB to 16GB costs £200, as does doubling the base storage from 256GB to 512GB – but there's enough power here to last you for years. **REVIEW Issue 343, p60**

Intel NUC Pro 13

If you don't need discrete graphics then Intel's mini PCs are a fantastic choice, being easy to upgrade, low on energy consumption and more than powerful enough to cope with Windows applications – despite being little larger than a coffee coaster. **Barebones, from £350; full PCs, from £600, from scan.co.uk REVIEW Issue 345, p48**

PCSpecialist Topaz Supreme

This is an all-AMD system, with a Ryzen 5 7600 partnered with Radeon RX 6600 graphics. That's enough for smooth 1080p gaming, and the Topaz also has 16GB of Corsair DDR5 RAM and a speedy 1TB SSD. At this price, it's simply fantastic value. **£899 from pcspecialist.co.uk/reviews REVIEW Issue 347, p54**

ENTHUSIAST PCs

Chillblast Apex Ryzen 9 RTX 4090 Gaming PC

7950X3D and RTX 4090 for £4,400

from chillblast.com

A brilliant choice if you're looking for easy expansion tomorrow coupled with cutting-edge gaming with high-quality components today. **REVIEW Issue 347, p52**

HP Omen 45L (2023)

We tested the top-end 45L with a Core i9-13900K, GeForce RTX 4090 graphics and 64GB of RAM, and it doesn't come cheap. Switch to the Core i7/RTX 4070 Ti version, however, and the price almost halves without losing any of the superb design and build quality. **£4,800 from hp.co.uk REVIEW Issue 347, p50**

Alienware Aurora R16

An understated yet stylish gaming PC that runs quietly even when pushed. This rig has power where it counts, mixing Intel's latest CPUs with Nvidia's RTX GPUs. Choose an RTX 4070 or higher to benefit from the glass side and liquid cooling, which lifts it above rivals. **From £1,349 from dell.co.uk REVIEW Issue 349, p54**

ALL-IN-ONE PCs

HP Envy 34 All-in-One

£2,099 widescreen wonder

from hp.com

Built around a high-quality 34in widescreen – which is perfect for viewing two windows side by side thanks to its 21:9 aspect ratio – this also comes with Nvidia RTX 3060 graphics. We're big fans of the magnetic 16-megapixel camera, too. **REVIEW Issue 335, p46**

Dell Inspiron 24 All-in-One

Despite being built to hit a price point, the Inspiron 24 All-in-One manages to look classy, include a good-quality, 1,920 x 1,080 24in panel and have enough power to breeze through a typical day's tasks. It even packs mod cons such as a 720p webcam. Superb value for money. **From £599 from dell.co.uk REVIEW Issue 350, p47**

Apple iMac 24in (M3)

The iconic design remains the same, but the plain M3 chip inside the revamped iMac 24in is a revelation compared to the previous M1 version. The downside is that the base configuration includes a stingy 8GB of memory and a 256GB SSD. **From £1,399 from apple.com/uk REVIEW Issue 352, p52**

CREATIVE WORKSTATIONS

NEW ENTRY

Scan 3XS GWP TR Ada

Record breaker for £14,167 exc VAT

from scan.co.uk

A 64-core Ryzen Threadripper 7980X blows everything that went before out of the water with multithreaded tasks, while Nvidia's RTX 6000 Ada graphics dominates for viewport acceleration and GPU rendering. Even storage throughput is unparalleled. With a striking chassis and brilliant build quality, you'll want for nothing. **REVIEW Issue 353, p52**

Armari Magnetar MC16R7

A strikingly fast workstation for the money, with Armari's customised liquid cooling extracting the most from an AMD Ryzen 9 7950X. With 64GB of DDR5 RAM and AMD's Radeon Pro W7800 in support, this is a fantastic value machine. **£3,758 exc VAT from armari.com REVIEW Issue 348, p84**

PCSpecialist Onyx Pro

Even in a creative workstation, it makes a lot of sense to include Nvidia's consumer graphics due to its core-per-buck. Here, an Nvidia RTX 4090 partners with a Core i9-13900K and an incredible 192GB of RAM to tremendous effect. **£3,750 exc VAT from pcspecialist.co.uk/reviews REVIEW Issue 348, p86**

TABLES

Apple iPad Pro 12.9in
Simply the best, from £1,249
from apple.com/uk

The best tablet out there thanks to Apple's powerful M2 chip, even if the upgrade prices sting in their usual fashion. In return you'll get a workhorse during the day (especially with the optional Magic Keyboard) and a brilliant entertainer at night. **REVIEW Issue 352, p84**

Samsung Galaxy Tab S9 Ultra
The best of the big-screen Android tablets, with the bonus of Samsung's DeX environment if you want to use it as a desktop replacement, while One UI lets you manage multiple windows and multitask between them. The 14.6in AMOLED screen is superb, too. **From £1,199 from samsung.com REVIEW Issue 352, p87**

OnePlus Pad
The OnePlus fully justified its place in our luxury tablet Labs thanks to its outstanding build quality, slick performance and stunning 17-hour battery life. It's the best Android option outside of Samsung's Galaxy Tabs – and it won't do nearly so much damage to your wallet. **£449 from oneplus.com REVIEW Issue 352, p86**

EVERYDAY PHONES

Motorola Moto G13
Amazing quality for £150
from johnlewis.com

If you only have £150 to spend on a phone then this is a simply brilliant choice. The camera produces superb results, the design is first class, and while it isn't the fastest performer it's fast enough – and the battery life is great. **REVIEW Issue 346, p73**

Google Pixel 7a
A phone that begs the question: why spend £150 more for the Pixel 7? With few compromises on the Pixel 7 – it uses the same processor and cameras and the only notable change is a smaller screen – this is the new mainstream pick for Google phone fans. **128GB, £449 from store.google.com REVIEW Issue 346, p68**

Motorola Edge 30 Neo
This stylish and compact smartphone – reflected by a small-ish 4,200mAh battery – includes a gorgeous 6.3in OLED screen, nippy Snapdragon processor and a decent pair of cameras for a great price. **£300 from motorola.co.uk REVIEW Issue 348, p73**

PREMIUM PHONES

Google Pixel 8 Pro
Big-screen wonder from £999
from store.google.com

A starting price of £999 is high compared to its predecessors, but we can't complain about the stunning camera setup or the all-round quality. It's a great showcase for AI in our phones, and seven years of Android updates only adds to its appeal. **REVIEW Issue 351, p70**

Google Pixel 8
It's not a huge step up from the Pixel 7, but the added AI features are genuinely useful and it benefits from a handful of upgrades, too – including a 120Hz screen and the new Tensor G3 processor. If you don't mind the lack of optical zoom, it's a great buy for the price. **128GB, £699 from store.google.com REVIEW Issue 351, p72**

Samsung Galaxy Z Flip5
While the Galaxy Z Fold5 has its undoubted attractions, the Flip5 pips it onto this A List slot thanks to it being £700 cheaper and through the usefulness of the expanded front display. It's also IP68 rated and packs a stellar chip, beating rival flip phones. **From £1,049 from samsung.com/uk REVIEW Issue 349, p70**

EVERYDAY MONITORS

Lenovo ThinkVision P27u-20
4K Thunderbolt, £550
from lenovo.com

We reviewed this when it cost £470, but even at £550 it's a superb buy. It's a top-quality 27in panel with a 4K resolution, and it packs superb connectivity, including Thunderbolt 4. **REVIEW Issue 344, p89**

AOC Q27P3CW
If you can't afford the ThinkVision P27u-20 then this 27in USB-C docking monitor, complete with solid image quality and a 1440p resolution, offers unmatched value at a shade over £300. It even includes a webcam that supports Windows Hello. **£310 from box.co.uk REVIEW Issue 344, p83**

Iiyama ProLite XCB3494WQSN
Curved 34in monitors proved a popular choice in our Labs, and although it had tough competition from the HP E34m G4 this Iiyama steals a spot on our A List due to Iiyama's twin focus on value and quality panels. There's even gaming potential. **£400 from scan.co.uk REVIEW Issue 344, p88**

PROFESSIONAL MONITORS

Eizo ColorEdge CG319X
Creative masterclass, £3,960
from wexphotovideo.com

As the price indicates, this monitor is for heavyweight creatives who demand the best in every discipline: HDR video editing, print layouts, professional photography and more besides. With superb coverage and accuracy across all spaces, plus a built-in calibrator, it justifies the investment. **REVIEW Issue 327, p81**

BenQ PD2725U
By no means a cheap 4K 27in monitor – unless you compare it to the Eizos – but it marries all-round quality with ease of use thanks to a puck that allows you to quickly move between settings. You can even daisy chain a second Thunderbolt 3 monitor for a monster setup. **£859 from photospecialist.co.uk REVIEW Issue 327, p80**

Eizo ColorEdge CG279X
Designers who need to work across different disciplines will love how easy it is to switch between the Adobe RGB, DCI-P3 and sRGB colour spaces using the Eizo's fantastic OSD. It's certainly not cheap for a 27in 1440p monitor, but it's packed with quality. **£1,726 from wexphotovideo.com REVIEW Issue 327, p84**

The A-List

WEBCAMS

Epos Expand Vision 1
Top-quality 4K video from £142
from uk.insight.com

Videoconferencing expert Epos claims the top spot with its first personal webcam. It delivers on all fronts: audio quality, colour accuracy and low-light performance, and all while undercutting the 4K Logitech opposition by £100.
REVIEW Issue 340, p74

Aukey PC-W3 1080p Webcam
If the thought of spending £142 on a webcam has you spluttering into your microphone then you should consider this far cheaper but high-quality alternative. Its colours are low-key in comparison to the best, but it still produces a sharp and detailed image. **£13 from ebay.co.uk**
REVIEW Issue 321, p72

Obsbot Tiny 2
This portable 4K webcam delivers for quality, design and sharpness, and it comes with a shedload of advanced features, including dynamic zoom and subject tracking. The only real downside is that it has a price that reflects its premium ambitions.
£329 from amazon.co.uk
REVIEW Issue 352, p75

HOME OFFICE PRINTERS   NEW ENTRY   NEW ENTRY   NEW ENTRY

Epson EcoTank ET-2830
Ink tank all-in-one for £250
from epson.co.uk

Don't expect flashy features, but do expect fast print speeds, high-quality prints, scans and copies, plus phenomenally low running costs – even after you've exhausted the 6,000 pages' worth of bottled ink that comes with it.
REVIEW Issue 353, p85

Canon Pixma TS8750
A fantastic choice for creative users that's equally at home printing photos as it is scanning artwork. Despite its high running costs, due to its reliance on cartridges, this is a superb all-in-one. **£159 from printerbase.co.uk**
REVIEW Issue 353, p86

HP OfficeJet Pro 9012e
So long as your print volumes aren't huge – the running costs mount up – this is a superb all-in-one for home office usage. It's fast, robust, prints double-sided and produces strong all-round results.
£208 from printerland.com
REVIEW Issue 353, p87

WORKGROUP PRINTERS   NEW ENTRY

Canon Maxify GX6550
Ink tank all-in-one for £392 exc VAT
from canon.co.uk

Designed to fit in tight spaces, this all-in-one includes a highly effective ADF and backs it up with high-quality prints at 24ipm in our tests. Running costs are superb, too.
REVIEW Issue 350, p58

Brother HL-L9430CDN
This laser printer (not an all-in-one, so there's no scanning or copying functionality) is a great choice for a busy office, producing sharp black text and making a good job of colour graphics as well. All while doing so quickly with a competitive price per page. **£415 exc VAT from printerland.co.uk**
REVIEW Issue 353, p84

Xerox B315DN
A fine alternative to the Brother and Canon, this mono laser multifunction printer produces superb results at great speed – 27.5 pages per minute in our 50-page test, which includes the spool time. It's similarly quick for scans, with a dual-CIS ADF to speed up double-sided copies. **£238 exc VAT from printerbase.co.uk**
REVIEW Issue 341, p87

WIRELESS ROUTERS   NEW ENTRY

Netgear Nighthawk RAXE300
Fast Wi-Fi 6E router, £350
from amazon.co.uk

The RAXE500 (*see right*) is faster than the RAXE300, but in practice we doubt you would notice – this tri-band router still delivered speeds between 50MB/sec and 150MB/sec in our tests. And it's packed with features, too. At £150 cheaper than its bigger brother, we think it hits the Wi-Fi 6E sweet spot.
REVIEW Issue 341, p68

Netgear Nighthawk RS700S
Make no mistake – you won't get stunning speeds out of this Wi-Fi 7 router today. But if you must buy a router now and want future-proofing, this is a solid choice. But honestly, we would recommend that you wait.
£800 from netgear.com
REVIEW Issue 353, p76

Asus RT-AX59U
You can buy cheaper Wi-Fi 6 routers – such as the D-Link Eagle Pro AI R15 for £55 – but Asus' well-priced offering delivers strong performance along with lots of control and exceptional VPN support. **£125 from uk.store.asus.com**
REVIEW Issue 350, p57

MESH WI-FI

TP-Link Deco XE200
Clever Wi-Fi 6E for £600
from amazon.co.uk

There are cheaper Wi-Fi 6E meshes, but the XE200 wins for its superb download speeds, excellent coverage and the fact that older clients reap benefits of 6E, not just new ones. And a two-pack (code B0BKTDPWC8) should be enough for most premises.
REVIEW Issue 349, p65

Mercusys Halo H80X
A new subsidiary of TP-Link, Mercusys offers its parent brand's XE75 router some excellent value-for-money competition. Not as fast due to Wi-Fi 6 rather than Wi-Fi 6E, but it has all the bandwidth you need for everyday use and should deliver it stably throughout your house. There are plenty of features too. **2-pack, £161 from ebuyer.com**
REVIEW Issue 341, p71

Linksys Velop Pro 6E
Ironically, this Wi-Fi 6E router will get the most out of your non-Wi-Fi 6 devices thanks to its use of the 6GHz network for station-to-station traffic. And you only need two units for rock solid performance across a three-bedroom house. **2-pack, £380 from amazon.co.uk**
REVIEW Issue 350, p54

BUSINESS WI-FI

Zyxel WAX640S-6E

Tri-band Wi-Fi 6E AP, £369 exc VAT

from broadbandbuyer.com

A nicely priced tri-band wireless access point ideally suited to businesses that want to provide the full range of wireless services. It's easy to deploy, wireless performance is good and Zyxel provides top-quality cloud management services. **REVIEW Issue 353, p100**

Asus ExpertWiFi EBM68
Small businesses will find much to like with this simple-to-manage Wi-Fi 6 access point. AiMesh makes it incredibly easy to expand wireless coverage, performance is reasonable and it includes an impressive range of network security features. **2-pack, £540 exc VAT from amazon.co.uk** **REVIEW Issue 353, p98**

Netgear WAX625
A great choice for SMBs seeking an easy wireless performance boost with minimum investment. This is an affordable Wi-Fi 6 AP with good speeds while Netgear's Insight provides smart cloud management services. **£224 exc VAT from broadbandbuyer.com** **REVIEW Issue 353, p99**

NAS SERVERS

Synology DiskStation DS1823xs+

10GbE NAS, £1,413 exc VAT

from broadbandbuyer.com

This powerful eight-bay NAS is a great choice for SMBs that want plenty of capacity, features and performance at a reasonable price. The new DSM 7.2 software has security high on its agenda, and the icing on the cake is Synology's generous five-year warranty. **REVIEW Issue 346, p101**

Qnap TS-h987XU-RP
The TS-h987XU-RP is a ready-made hybrid storage solution for SMBs. This rack-friendly package offers a great specification for the price, and Qnap's QuTS hero software scores highly for its wealth of data-protection features and business apps. **Diskless, £3,292 exc VAT from broadbandbuyer.com** **REVIEW Issue 344, p96**

Synology DiskStation DS1522+
Small businesses that want a high-capacity desktop NAS at a good price will find Synology's DS1522+ a great choice. Performance over 10GbE is impeccable and the DSM software offers a fantastic range of storage features. **5-bay NAS, diskless £586 exc VAT from broadbandbuyer.com** **REVIEW Issue 344, p98**

VIDEOCONFERENCING

Poly Studio X52 with TC10

Perfect middle man, £3,161 exc VAT

from meetingstore.co.uk

Ideal for businesses that want a professional videoconferencing solution for medium-sized meeting rooms. Video quality is excellent, speaker tracking fast, and the big choice of built-in VC apps makes it incredibly versatile. **REVIEW Issue 353, p102**

Owl Labs Owl Bar
As a standalone videoconferencing room solution the Owl Bar has plenty to offer, with good video quality and super-smooth speaker tracking. It really comes into its own when paired with an Owl 3, though, as this unleashes a completely new dimension to your meetings. **£1,999 exc VAT from owllabs.co.uk** **REVIEW Issue 352, p99**

Epos Expand Vision 5 Bundle
Perfect for SMBs seeking an affordable Microsoft Teams Rooms solution with seamless BYOD support. Video and audio quality is good, speaker tracking is smooth and the Control tablet makes meeting room management a breeze. **£1,915 exc VAT from misco.co.uk** **REVIEW Issue 352, p97**

SCANNERS

Xerox D70n Scanner

Fast and furious, £765 exc VAT

from ballicom.co.uk

The D70n delivers a mighty scan speed together with a wealth of scan management tools and apps. Businesses that want a high-volume networked desktop scanner at an affordable price should put the Xerox at the top of their list. **REVIEW Issue 346, p99**

Brother ADS-4700W
A fine choice for small businesses, with an impressive range of scanning features at a price that can't be faulted. Output quality is top notch and the versatile LCD touchscreen menus provide great walk-up scan services. **£355 exc VAT from printerbase.co.uk** **REVIEW Issue 346, p96**

Epson WorkForce ES-C380W
An affordable choice for offices short on space. It delivers on its 30ppm speed promises, Epson's ScanSmart software offers plenty of management features, and its standalone mode makes it very accommodating. **£280 exc VAT from ballicom.co.uk** **REVIEW Issue 351, p101**

SERVERS

Dell EMC PowerEdge T350

Xeon E-2300 power, from £1,399 exc VAT

from dell.co.uk

Perfect for SMBs and branch offices looking for an affordable and powerful single-socket tower server. Along with support for Xeon E-2300 CPUs and lots of memory, it has a high storage capacity, plenty of expansion space and is sturdily built. **REVIEW Issue 335, p98**

Dell EMC PowerEdge R250
With prices starting at around £850 exc VAT for a Pentium Gold CPU, and the option of Xeon E-2300 series chips from £1,461 exc VAT, this is a slim, rack-mounted alternative to the more high-powered T350 that's ideal for SMBs. **From £845 exc VAT from dell.co.uk** **REVIEW Issue 332, p98**

Broadberry CyberServe Xeon E-RS100-E10
This represents a powerful hardware package at a price that will please small businesses. We love its low-profile chassis and the fine selection of remote-management tools. It's a great alternative to the Dell EMC servers also listed here. **£983 exc VAT from broadberry.co.uk** **REVIEW Issue 318, p96**

SECURITY SOFTWARE

G Data Total Security
A suite for power users with a host of useful features that offers formidable protection against viruses. **5 devices, $82 per year (first year and renewals) from gdatasoftware.co.uk** **REVIEW** Issue 343, p83

Avast One Essential
The only product in our tests to score a 100% protection rating for blocking all malicious files, this reliable choice is our pick of the free AV tools available and includes a free if limited VPN service. **Free from avast.com** **REVIEW** Issue 343, p82

McAfee+ Advanced
A high-end choice with high-end features and support for an unlimited number of devices. Good value for the first year, but watch out for renewals. **Unlimited devices, £75 first year, £150 renewals from mcafee.com/en-gb** **REVIEW** Issue 343, p84

VPNs

NordVPN
NordVPN won our VPN Labs for the second time running thanks to its consistent, fast speeds, great security features and excellent support for video streaming. **£80 for two years from nordvpn.com** **REVIEW** Issue 349, p86

ProtonVPN
The best free VPN service available, with quick speeds and unlimited bandwidth. The paid-for service isn't cheap, but offers a bunch of useful extra features that might just tempt you into coughing up. **Free from protonvpn.com** **REVIEW** Issue 349, p88

Surfshark
The fastest VPN we've tested, and it's generally a good performer in our region-shifted streaming tests, too. Cancellation is trickier than it should be, but it's a great-value choice for heavy VPN users. **£56 for two years from surfshark.com** **REVIEW** Issue 349, p89

PASSWORD MANAGERS

NordPass
This hassle-free option is a great choice for both personal and business use, with a competitive price matched with all the features most people need. **£1.89 per month from nordpass.com** **REVIEW** Issue 350, p70

Bitwarden
Free for individual use and open source, the only important thing Bitwarden lacks is phone support: it works with virtually every device and browser, and the paid option is well worth £10 per year. **Free from bitwarden.com** **REVIEW** Issue 350, p71

Keeper
A great choice for businesses thanks to its focus on security and a zero-knowledge policy, and if you need more options then Keeper has them. **Business edition, from £2 per user per month from keepersecurity.com** **REVIEW** Issue 350, p72

ENDPOINT PROTECTION

Sophos Intercept X Advanced
Delivers a huge range of endpoint protection measures for the price. It's simple to deploy, device and user policies add flexibility, and seamless integration with the Sophos Central cloud portal makes management simple. **500-999 users, 1 year, £36.50 each exc VAT from enterpriseav.co.uk** **REVIEW** Issue 351, p98

WithSecure Elements EPP and EDR
High levels of automation make WithSecure a great choice for SMBs that want endpoint protection on a plate. It's simple to deploy, offers a wealth of security features and is easily managed from the cloud. **100-499 devices, £37 each per year exc VAT from withsecure.com** **REVIEW** Issue 351, p99

BUSINESS BACKUP

Veritas Backup Exec 22.2
Our top pick for on-premises data protection, Veritas Backup Exec 22.2 offers a superb range of features, great value and backs this all up with swift deployment and an easy-to-use interface. **Simple Core Pack, 5 instances, £389 per year exc VAT from uk.insight.com** **REVIEW** Issue 350, p97

IDrive Business
SMBs that want affordable cloud backup and data recovery features will appreciate IDrive Business, with its extensive app and platform support. **2.5TB, £479 exc VAT per year from idrive.com.** **REVIEW** Issue 347, p99

VOIP SERVICES

3CX
SMEs worried about the cost and complexity of hosting an IP PBX will love 3CX's free offering. It's easy to use and provides all the call-handling services you need. **Free for 1-10 users from 3cx.com** **REVIEW** Issue 345, p96

Gradwell Wave
Ideal for SMEs that want the smoothest possible path to VoIP, this cloud-hosted service is easy to manage and packed with features. **Wave 100, from £7.50 exc VAT per user per month from gradwell.com** **REVIEW** Issue 345, p98

NETWORK MONITORING

Progress WhatsUp Gold 2022
Easy to deploy, and with flexible device-based licensing plans, WhatsUp Gold is an affordable choice for SMBs. It presents an impressive set of network-monitoring tools in a well-designed console and tight integration with the LoadMaster and Flowmon apps. **50 devices, Premium, yearly licence, £1,309 exc VAT from whatsupgold.com** **REVIEW** Issue 342, p90

Paessler PRTG Network Monitor 22.4
The ability to assign sensors to any device brings versatility, and everything is included in the price so there's no need for optional modules. **1,000 sensors, 1yr maintenance, €2,499 exc VAT from paessler.com** **REVIEW** Issue 342, p89

REMOTE SUPPORT

IDrive RemotePC Team
IDrive's RemotePC Team will appeal to SMBs that want affordable cloud-hosted remote support for their offices and home workers. It's exceedingly simple to deploy, easy to manage and delivers tough access security measures. **First year, 50 computers, £172 exc VAT from remotepc.com** **REVIEW** Issue 349, p98

NetSupport Manager 14
Delivers a wealth of support tools, including secure access to home workers, and licensing plans are good value. **1-500 systems, perpetual licence, £10 each exc VAT from netsupportmanager.com** **REVIEW** Issue 349, p100

UTM APPLIANCES

WatchGuard Firebox T45-W-PoE
Offering enterprise-class gateway security measures at an affordable price, this is a great choice for small to medium-sized business and remote offices. Integral Wi-Fi 6 services add extra value and it can be easily managed and monitored from WatchGuard's slick cloud portal. **Appliance with 3yr Total Security Suite, £3,148 exc VAT from guardsite.co.uk** **REVIEW** Issue 348, p98

Zyxel ZyWALL ATP500
This desktop appliance gives sophisticated protection against zero-day threats, is easily managed and very good value. **Appliance with 1yr Gold Security licence, £1,191 exc VAT from broadbandbuyer.com** **REVIEW** Issue 348, p99

Rental hygiene: why we should refuse to pay

Dick Pountain is editorial fellow of *PC Pro*. He finds the ads on Facebook more hilarious than most of the content. Email dick@dickpountain.co.uk

The push towards subscription models is painful for us as consumers, but ultimately it's going to hurt the companies behind it, too

My ideas for this column often come from newspaper stories, and this one was about Meta. Also known as The Corporation That Used To Be Called Facebook, or TCTUTBCF for short. TCTUTBCF has just launched ad-free, subscription-only versions of Facebook and Instagram to comply with a new EU privacy law. That law, first deployed in Norway, prohibits tech companies from forcing users to agree to targeted advertising to use their products. The user must be free "to individually refuse consent to certain data processing operations… without being forced to completely waive the use of the service".

Meta responded by offering paid subscription versions of Instagram and Facebook as "a valid form of consent for an ad-funded service". This means all the major online platforms that offer a "free" ad-funded version now also provide a subscription or rental alternative. Google has YouTube Premium, while content providers such as Netflix and Disney+ both offer a discounted version of their "standard" plans if people are willing to put up with ads.

Economists of both left and right tend to frown upon "rent-seeking" – making money from what you own rather than what you make or do – as it stifles innovation and competition and is often a symptom of monopoly. That's as may be, but there are cases (water, electricity) where renting a service is the only sensible route – Margaret Thatcher's attempt to get us to own a slice of them fizzled within months as people sold their windfall shares to buy widescreen tellies.

> **What has me irritated is the wave of small and far-from-essential vendors rushing into the rental-only model**

Personally, there are few software services I use often enough that subscription makes sense, but I do rent 100GB of cloud storage from Google for a very reasonable £20 per annum. What has me seriously irritated, though, is the recent wave of small and far-from-essential vendors rushing into the rental-only model, presumably as a survival tactic in the face of dwindling revenues.

I recently went shopping for several music-related Android apps, including a guitar chord guide, a digital audio workstation and a video editor, and was astonished to find that so many of the competent ones now employ the same come-on: a seven-day trial but give us your credit card number *now* (tantamount to inertia selling, the weapon of encyclopaedia salesmen through the ages). I eventually found one of each that was good enough and offered an old-fashioned "give us £X to remove the ads and own it" deal, with which I'm happy.

A similar Gadarene rush into rent-seeking has infected many of the information sources I've relied on for years, which have started teasing with the first few paras of an article before greying out the rest and demanding cash. I'm prepared to pay a reasonable sum for a single article (though many academic sites want far-from-reasonable bucks, assuming your institution is paying) but I really don't need another monthly subscription.

I'll confess that over the years I've cultivated an Artful-Dodger-like skill in getting over, around or under paywalls: once it was enough just to Google the article title outside the site (they got wise to that), then more exotic tricks such as reading the Pocket-saved version (they got wise to that too). Now I just don't bother with them as I've too much to read anyway.

> **Over the years I've cultivated an Artful-Dodger-like skill in getting over, around or under paywalls. Now I just don't bother with them**

This is not a traditional kind of rent-seeking, exploiting a monopoly over an essential service; it's vendors manipulating the sheer ease of the buy-now, one-button-press billing/payment process to convert customers to subscriptions they neither want nor need. It's always been a problem for software suppliers that their products are expensive to develop, cheap to copy and become out of date quickly. Rental can look like a solution to all those problems, but it diminishes the incentive to innovate or improve features: shrink to a skeleton team of maintenance developers, move to a subscription model, hey presto your revenue becomes almost pure profit. This keeps investors happy and pressures your competitors toward a rent-seeking model, too.

But if people can be persuaded that digital goods aren't like physical goods, renting them may weaken ownership rights over a purchase that can be turned off if you don't pay up. This is what has the EU worried, not just about the services themselves but about users' private data – invalidating ownership rights without the explicit consent of the owner is tantamount to theft.

Call me old-fashioned but I prefer to own the tools of my trade. I carry out frequent audits of my subscriptions, and dump without mercy. I suspect I'm not alone, and that means one thing for all those companies who've rushed to subscription models and will no doubt staunchly defend them: such short-term thinking may end up being an existential threat.

dick@dickpountain.co.uk

Tech should let us work less, not more

A brain-tech startup wants to tap our dreams to put us to work while we sleep, which is anathema to nap lovers

Nicole Kobie is *PC Pro*'s futures editor. She really, really needs a nap, okay?
@njkobie

I will pay anything for technology that will help me sleep. Not that I have difficulty sleeping – I can doze off standing in a crowd. Instead, what I have is obstacles in the way of rest, usually in the form of day-to-day life – a job with tasks, a home with chores and demanding loved ones. Here I'm talking less of my young child and more of my dog, who both at times require middle-of-the-night attention because they've peed.

When my toddler was a newborn, I bought her a sheep that glows red and plays soothing sounds when squeezed or when it detects motion or noise, which supposedly helps infants back to sleep. Does it work? A bit. Ewan the Sheep, as he is called, probably helped me get an hour or two extra back when that really meant something, and for that I adore the £40 pile of glowing fluff.

But tech doesn't need to be directly about sleep to allow me to nap. Any tool that helps me research, write and invoice faster means I can nap sooner. The entire point of technology is convenience, as far as I'm concerned, though you can call it "efficiency" and

> **It's a slippery slope into a workplace dystopia where a part of our brain answers customer emails while we watch Netflix**

"productivity" if you must. Googling is faster than flipping through the Yellow Pages. Amazon Kindle is easier than going to the library. Email is quicker than writing a letter, licking a stamp and walking to the postbox. All of these save me time, and saved time – in my house, at least – is nap time.

So when I first read about the Halo, a "non-invasive neural device" from a startup called Prophetic, I thought I must be dreaming – and that it must be a nightmare.

Halo is a neurostimulation headband you wear while you sleep that beams ultrasound signals into your brain to help induce "lucid dreaming", which is when you can control your own dreams. The startup believes lucid dreams are the key to creative genius; founder Eric Wollberg told *Vice* it was the "ultimate VR experience".

That sounds fun. What could we do with it? One suggestion Wollberg gave *Fortune* is to work. Programmers could take control of their dreams and, rather than exploring the edges of human consciousness, they could get some coding done. Managers could practise presentations. It's a slippery slope into a workplace dystopia where a part of our brain answers customer emails while we binge-watch Netflix, or bosses upload company problems to be solved in blue-sky brainstorming sessions via shared lucid dreams.

None of this is yet possible. The device isn't out until 2025, and we don't even know if it works. The science isn't in to confirm ultrasounds beamed into your skull will actually spark a lucid dream or not, or even if most of us could control the dream, *Inception* style. Indeed, the company's "scientist collaborators" admitted to *Slate* last October that they'd built the technology before successfully sparking a lucid dream. Not a single one.

Even if the headband manages to induce lucid dreaming, the other half of Prophetic's Halo technology still needs to decode what's going on, to spot the right types of dreams and learn what techniques are successful – that's the work of co-founder Wesley Berry, and it naturally uses AI to try to read brain frequencies. This idea crops up time and time again, that machines can unpick what we're thinking; hopefully one day the challenge is solved, not so we can code while asleep but so those with locked-in syndromes and similar disorders can communicate.

It appears that your dreams are safe, for now. But what we do know is that given the ability to control dreams, Silicon Valley can

> **When given the ability to control dreams, Silicon Valley can only imagine a world of improved productivity and limitless coding**

only imagine a world of improved productivity and limitless coding. This isn't just dull, but unhealthy. Ambitious people may see time spent sleeping as a waste, but humans are extremely productive at sleep. It's when we heal, our bodies racing to repair the damage from the daytime and even to fight illnesses – that's one reason why fevers spike at night, as your immune system kicks into gear. As we sleep, our brain also figures out everything we've learned; though we don't really understand how this all works, it's clear that a good night's sleep helps us retain information.

Work already demands too much of our time, with notifications buzzing watches, email responses expected in minutes and Zoom meetings mushing the boundary between home and the office. I'm writing this at my desk in my home office, which also happens to be my bedroom. Technology has crept far enough into my life that I sleep next to my monitor and work in view of my pillow.

Tech should give us more free time, not chain us further to head office. If you're less beneficial to my sleep than Ewan the Sheep, you're not an innovation I want in my bed.

work@nicolekobie.com

Microsoft needs to become a more reliable parent

Barry Collins is a former editor of *PC Pro* and a father of two. They pay no attention to him.
X @bazzacollins

Windows 10 is the latest example of a Microsoft U-turn on operating system life support, but it's not the first – and the kids are losing respect

The best bit of parenting advice I ever received was "don't make empty threats". If the little tykes are redecorating the lounge walls a daring shade of Crayola, don't threaten to withhold all their birthday presents, because you won't do it – and the little baskets know you won't.

It feels like Microsoft could have benefited from watching this episode of *Supernanny* (or wherever I gleaned that gem from) because every time we near the end of a version of Windows, Microsoft's threats are emptier than a branch of Wilko's. "We're going to end support on such-and-such a date," warns Redmond. "No you're not," the world replies, continuing to run a felt-tip pen down the bannisters.

We reached this stage of false jeopardy recently with Windows 10. Microsoft has long insisted that the OS will reach end of support in October 2025, but the backsliding has already begun. Businesses that want to run Windows 10 machines after the cut-off date will now have the safety net of Microsoft's Extended Security Updates, available for another three years after the 2025 deadline.

What's more, for the first time, Microsoft will offer Extended Security Updates to consumers, meaning your Uncle Graham can keep his Dell tower patched for another few years – for a yet-to-be-disclosed price.

We've been here before, of course. Microsoft failed to impose its own end-of-support deadline for Windows 7, with "mainstream" support officially ending in 2015, but extended support running for a further five years. Every year, Microsoft just increases the price of extended support a chunk higher until it becomes unpalatable for most.

Before you start emailing in with your carefully crafted Microsoft defences, I also find it hard not to have sympathy with Microsoft here. If it stuck to its guns and refused to extend support, you'd have millions of businesses and consumers running an operating system that's wide open to attack. If it keeps extending the support deadline, rent-a-columnists like me have a pop at the company.

But let's not pretend that extended support is good for anyone. For big organisations such as the NHS, it will cost an arm and a leg (pun absolutely intended) to shell out for extended support. When Windows 7 finally dropped off its extended support perch, a third of NHS computers were still running it. Not only does this mean taxpayers' money was being wasted on keeping expired operating systems secure, it tells us that the equipment we rely on to keep the NHS functioning is woefully out of date.

For consumers, it will mean yet another subscription to add to the pile – although I suspect few will actually pay. The reason many haven't shifted to Windows 11 systems in the first place is that they can't afford new hardware that runs the OS smoothly. Even if they understand the benefit of extended support (by no means a given), they surely won't be eager to pay for it. GoCompare claims that around a quarter of UK residents don't have home contents insurance – how many of those people are going to pay for Patch Tuesdays?

Although Microsoft may well lap up significant extra revenue for these extended support deals, it isn't good for the company to keep having to put operating systems on life support. It wastes

> **Every time we near the end of a version of Windows, Microsoft's threats are emptier than a branch of Wilko's**

resources, it wastes developer time, and it's just a bad look for Microsoft that – two years after the release of Windows 11 – Windows 10 still has a 60% market share of the Windows desktops, according to Stat Counter.

So, here's my solution, for the business market at least: Windows LTS. Instead of Windows 12 Pro, Microsoft creates a lean, no-frills, long-term support version of Windows for businesses that it guarantees to support for ten years. But not a day longer.

After five years, and every five years thereafter, it releases another LTS version of Windows, giving big organisations such as the NHS plenty of time to sort out their migrations before the hard deadline. Businesses are no longer blindsided by new Windows releases, such as the way Microsoft suddenly pulled Windows 11 out of the hat. They have predictable, twice-a-decade release schedules that give them no excuse to still be running outdated OSes after the support deadline ends.

The tech world (and press) often focuses on the cutting edge, but stability and predictability are far more important to businesses. By implementing a clear, long-term support strategy with Windows LTS, Microsoft could profit from the principle I mentioned at the top of this column: follow through on your promises. No more empty threats, no more last-minute reprieves – just solid, dependable parenting, with a set bedtime that's clear to all involved.

barry@mediabc.co.uk

> **When Windows 7 finally dropped off its support perch, a third of NHS computers were still running it**

Readers' comments

Your views and feedback from email and the web

Regulation for R2R

As a reader since issue one (nearly 30 years ago!), I read issue 352's star letter and felt I had to jump to the defence of Tim and Lee. As someone who has been involved with the procurement of computing devices for large enterprises for over 20 years, I would side with Lee on the issue of "right to repair" as an example where regulation (or the threat of) was needed to steer the self-regulating free market in a different direction.

I can think of many examples where hardware manufacturers put form or technical aspirations over repairability or environmental considerations or even common sense for the general consumer – Apple and Microsoft being two culprits who only recently have had to change some of their design decisions based on regulatory influence around the serviceability of their devices. I'm not sure if either of these organisations would have made the changes they had, if it wasn't coordinated through regulatory bodies.

Even having been through the recent changes both Microsoft and Apple have had to implement, such as

ABOVE The threat of regulation has helped push the right to repair

USB-C charging for iPhones and not glueing the screen in the chassis (Microsoft), both have opted to use proprietary charging ports in their Mac and Surface despite the world moving to USB-C. Yes, we're free to not buy those devices, but is that really the best approach? Do we have to go through a VHS vs Betamax-esque war every time a new solution is created just to get the best outcome for consumers and the environment?

I will agree with Andy, the letter's author, that time and again our politicians have proven they are not best placed to make technology decisions – but that says more about the state of the politicians we have than anything else in my view.
Mike Webb

AI safeguards

First, let me say how much I enjoy the magazine: I look forward to it every month and read it far too quickly. I particularly enjoyed Dick Pountain's column (*see issue 351, p20*) reflecting the views of Yuval Noah Harari on the dangers of AI and how it might be controlled. I remember in the 1970s when it became clear that genetic engineering was a possibility that some of the scientists working in the field agreed a moratorium on the work until a set of controls had been put in place. This was sparked by the famous "Berg letter" (famous if you're a biochemist like me, that is!) written by Paul Berg – subsequently a Nobel Laureate – that resulted in a conference at Asilomar which basically put in place the system for containment of genetic experiments that is still used today.

The parallels with the suggested dangers of AI are stark, but it's interesting that this time, the rush to profit will overcome any desire to protect us from something that might in its own way be as threatening as genetic engineering. I can't see the big AI companies sitting down to agree safeguards any time soon.
Steve McClue

Star letter

Sending the wrong signal

In a few podcasts now there has been talk of software as a streaming service, for example discussions around Windows, but what is often overlooked is that the UK's data network is just not up to this. I work all over the mainland UK in a mobile health clinic; last week was Newcastle and Inverness, this week has been King's Lynn, Weymouth and now Maidstone, so I am reliant on decent 4G and 5G networks. To help with this I have two contracts on my phone, EE and O2, with the idea being I can use one when the other is not so great. (In practice, that means EE 80% of the time.) But all too often there is no usable signal at all.

Today I am in Maidstone but have no usable 4G or 5G signal on either network, and the same was true in both King's Lynn and Weymouth. All technically have 4G and 5G, but not where I am

actually located in the towns, meaning I've not had usable coverage at a single location all week. For the last 45 minutes I've been trying to find some urgent information for work (okay, if I'm honest it was "who played Boss Hogg?"), but my phone can't even open a search page, much less the laptop to do anything more data-hungry.

In a recent podcast Jon rather optimistically said Wi-Fi is everywhere so that solves it, but Wi-Fi is not an option. For example, right now there are no networks at all, while at other times there are networks but they're locked with no visitor access. Also, I have an annual account with the purple hotels so beloved of Lenny Henry, but while some of those are good, on other occasions it's unusably bad and has to be turned off. Wi-Fi is just not widely available enough as a fall-back.

The software companies seem to be trying to sprint in one direction, but the track they are running on hasn't been built yet. It's great if someone works in the same place every day or

at least always works in a nice office with the infrastructure to support that, but if you're out and about the UK's data coverage is absolutely abysmal. I can genuinely get a better mobile data connection in the middle of the Channel Tunnel than the middle of some Birmingham industrial estates, and streaming something like Windows is just pie in the sky that's never going to happen in my lifetime.

Yes, I could get a mobile Starlink setup, but that means giving Mr Musk money, so that's not happening.
Adam Jackson

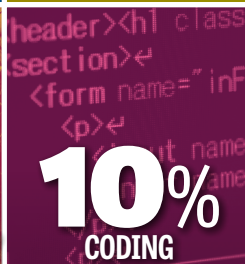**Editor-in-chief Tim Danton replies:** Thanks for sharing all this experience, Adam. It's great to hear what coverage is like around the country, as those coverage maps can occasionally feel like works of fantasy.

This month's star letter writer wins a Cherry KC 200 MX mechanical keyboard, worth £80, recipient of a five-star review and a *PC Pro* Recommended award. Email letters@pcpro.co.uk

Smart thoughts

Your article on smart homes (*see issue 351, p76*) was – as always – clear, detailed and interesting. However, I believe that you missed one area: that of power and internet connectivity. In my small local community, we have occasional power cuts and, separately, fairly frequent internet outages. This is not some isolated village miles from anywhere but a community less than 30 miles from the centre of London and inside the M25. Any smart system used here needs to be able to deal with power cuts and/or loss of internet connectivity seamlessly.

One particular area of worry is that of security. Camera doorbells such as Ring are very popular for remotely monitoring who is at the door. However, these and similar internet-based remote security systems will be useless if either power or web connections are unavailable. Additionally, will all the controllers resume properly after a power or internet interruption? Uninterruptible power supplies (UPSes) may be one solution, but how long will they last and are the switch-in/switch-out transients acceptable for the smart network? Perhaps a Labs test subject?

For the truly paranoid, wireless networks must be invulnerable to a dedicated jamming attack. GPS jammers are already available fairly readily, albeit in a different frequency band. What happens if a Wi-Fi network is jammed? How would the smart devices respond to simple jamming? We have all heard of thieves exploiting keyless car security so as to steal the vehicle in question.

Many thanks for an interesting magazine.

Alistair Dunlop

Readers' poll

Turn to p26 and you'll discover how to create your personal AI assistant (and more besides). So what, we wondered, would our readers like a personal AI to do for them?

27% HOUSEHOLD CHORES
13% TRIAGE MESSAGES
10% DEAL FINDING
10% KEEP OUT OF MY WAY
10% CODING
7% WAKE ME UP
7% FANTASTICAL

Microsoft may be pumping its research dollars into AI assistants that make us work more efficiently, but it turns out that what we really want is domestic help. "I have been told since an early age, peak tech is making a cup of tea," said Michael Dear. "But I would like a lawn mower that doesn't need setting up and will go around the flowers." We hear you, Michael.

Marc (@DebuggingForFun on X) has other priorities, wanting his AI assistant to "redecorate any room in my house". Maybe in ten years, but don't hold your breath. We think Quillon Fox's request (@quillon1 on X) is closer: "Produce a weekly food menu for me and my wife. Why? We've been cooking for kids etc for over 30 years, and had enough. Just tell me what I'm eating tonight so I don't have to think. Well worth the trillion-dollar development costs."

Andrew Pepper has issues with his smart speakers. "Not entirely the assistant's fault, but trying to get one to play specific episodes of a radio programme from the BBC hovers on the impossible," he wrote. Before going one further: "Getting one to act like a clock radio – to wake me up at a specific time playing specific stations – is (apparently!) impossible."

Several people mentioned that it would be great to have an AI assistant that could help them find deals. "Make sure I am on the lowest tariff for gas, electric, broadband, mobile and other items I have to seemingly have to renegotiate every other day," requested Mike Gannon.

Others wanted nothing to do with it – and we'll leave the final word to Mark Walsham. "Write code that would ultimately result in the end of all this AI nonsense," he wrote. "I don't want my prostrate exam to be done by AI."

❝ Fold laundry. ❞ @bigajm

❝ Monitor my sleep states, then set an alarm that will wake me up when I'm most likely to feel rested. ❞ Joe Cowell

❝ Not. One. Darn. Thing. ❞ Debby Hanoka

❝ Turn my wheelchair into a hovercraft so I can fly above people and they look up at me rather than look down on me. ❞ Jamil Khan

❝ Filter spam callers, keep them talking, waste their time and frustrate them. ❞ John Wright

Join the debate

f Join the growing *PC Pro* community on Facebook at **facebook.com/pcpro**

✗ Get the latest news and updates by following us **@pcpro**

@ Email us at **letters@pcpro.co.uk**

ChatGPT masterclass
Make AI work for you

Want to get more from the best-known AI service on the planet? Barry Collins shows you how to make AI work for you

ChatGPT is a splendid time sink, letting you plot out horror movies starring Michael Stipe and Liz Truss, or practically anything else you can dream up. But it's a lot more than a plaything to pass a tea break with.

OpenAI's chatbot has a series of formidable features, most of them hidden from those who don't subscribe to ChatGPT Plus. It's worth doing, even if only for a month, so you can evaluate the sheer power that lurks here and work out if it could make a difference to your life.

ChatGPT Plus can perform hugely sophisticated data analysis, saving you from having to spend time learning how to do it yourself in applications such as Excel. It can tidy up your computer code, your emails or your PowerPoint presentations. It can hook into third-party services to plan holidays, book restaurants or scour for facts on your behalf.

And that's before we get to ChatGPT Plus' most impressive feature: GPTs. These are mini-chatbots, personalised to a specific task that you define. They can help you to cook dinner, organise a marketing plan, create graphics for social media or learn CSS. At the risk of tipping into hyperbole, there are virtually limitless applications for GPTs, and you can create and train them without having to bash out a single line of code. They're made with plain English commands and can be trained on your own data, so that they're highly personalised to you or your business.

In this feature, we'll guide you through how to master ChatGPT and GPTs, unlocking the potential of the AI assistant, with practical hands-on tips and advice.

MASTERING CHATGPT

There can't be a *PC Pro* reader out there who hasn't spent at least ten minutes noodling with ChatGPT – or one of its many derivatives, such as the Bing Copilot.

While there's plenty of AI power and much to explore with the free version of ChatGPT, the real power is unlocked when you subscribe to ChatGPT Plus. Not only does that (largely) ensure you can get access to the chatbot during the regular periods of peak demand where the free version is switched off, it also opens up extra features such as plugins and advanced data analysis. Let's look into those two features in greater detail.

Plugins

Plugins allow you to combine the intelligence of ChatGPT with third-party sites or services, such as Wikipedia, WolframAlpha or OpenTable. For example, you

with the US site, but it's good for generating ideas and rough budgets.

Irritatingly, you can only enable three plugins at a time and the Plugin Store is poorly presented and erratic. Often plugins don't install at the first time of asking, for example. It's a work in progress, but one that holds tremendous promise if it can be made to work more smoothly.

Advanced data analysis

This is arguably the best feature of ChatGPT Plus, although you may still need to dive into Settings | Beta features and switch it on first. Advanced data analysis lets you upload spreadsheets and other files and get the AI to do the hard graft that you might normally do in Excel.

For example, we fed ChatGPT Plus raw survey data from the *PC Pro* awards in an Excel workbook. Each tab represented a different awards category, and the AI automatically figured this out, but

are much more reliable than they are with general chats. There are no hallucinations (at least none that we've seen), and it will tell you if it can't perform a particular request or needs more guidance on what you're looking for.

ChatGPT prompt engineering tips

Although AI services such as ChatGPT are growing ever more intelligent and are remarkably capable at determining intent, there are techniques you can apply to guarantee faster, more accurate results. This so-called prompt engineering is often sneered at in tech circles, but knowing how to get the best results from AI tools is a skill – one that can pay handsomely, too, if you check the job ads.

We've only got space to cover the raw basics here, but even these tips should help improve your hit rate with services such as ChatGPT.

There are different types of prompt, the most basic of which is known as zero-shot prompt. This is basically where you give the AI a task without any clues as to the type of output you're seeking. For example:

Tell me the sentiment of the following social media post: the latest issue of *PC Pro* **was one of the best in years**

When we entered that into ChatGPT, it correctly identified it as positive. Of course you don't need an AI assistant to tell you that, but now imagine that you're pasting 3,000 of these social media sentiments into a spreadsheet and want to tell how many are positive – that's a job AI will perform far more quickly than any human.

To help improve the accuracy of results, you could give the AI clearer instructions of the output you're

LEFT **Plugins allow you to combine ChatGPT with third-party services**

BELOW **ChatGPT helped us produce the results for the** *PC Pro* **awards**
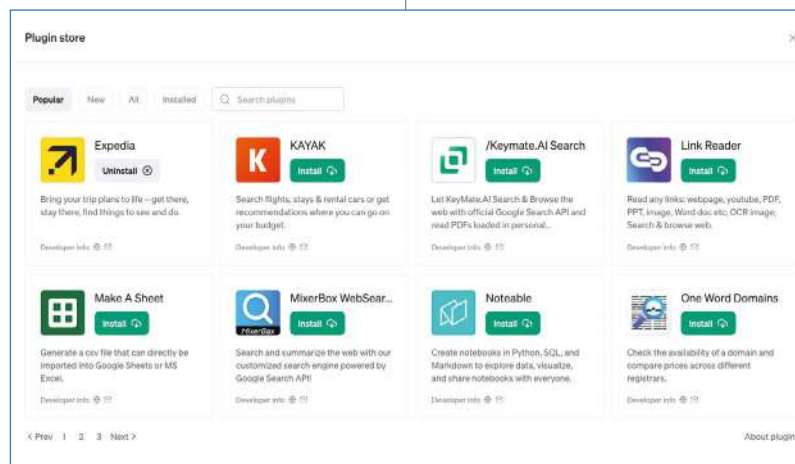
could ask the AI to create a summary of a long article you've found on Wikipedia or use it to research facts. And it goes further. Ask ChatGPT to "give me the release dates of the past five versions of Windows from Wikipedia" and it will even dig out the correct answers from the online encyclopedia, without you having to wade through different articles yourself.

With the Expedia plugin, on the other hand, you can ask the AI to do things such as create a three-day trip to Oslo for you, and it will come back with hotel and flight recommendations that suit your budget. It's not perfect: it sometimes gets trip dates wrong when you click through to book flights, for instance, and it only deals

checked this with us to ensure it was making the correct assumption.

Once it had worked out the format, we could ask it to produce graphs showing each company's performance in different categories or to tell us how company A fared against company B in different categories. We could also use it to calculate different weightings for each category, for example giving "very satisfied" responses a +2 weighting, but mere "satisfied" a +1, to see what effect that had on the overall results.

All of this could be done in Excel, but only if you have the skills with pivot tables or can apply the relevant formulae. Advanced data analysis lets you do all this with plain English commands, and the results

looking for and provide examples. This is called a few-shot prompt. So, to elaborate on the example above, we might enter the following few-shot prompt:

Tell me the sentiment of the following social media post and categorise it as either positive, neutral or negative. Here are some examples:

The latest issue of *PC Pro* was one of the best in years.
Answer: positive

Barry Collins couldn't write a bus ticket.
Answer: negative

The Labs was good, but I didn't get much from features.
Answer: neutral

Here we not only define what output we're seeking (positive, neutral or negative), but we give the AI something to go on with supplied examples. These are, of course, very basic examples that any AI model should be able to determine on its own, but you can apply the same technique to far more complex, nuanced scenarios where the answer might not be as clear-cut to help improve your results.

In the example above, ChatGPT rightly identified the third example as neutral – it contained good and bad feedback. So now you could let it loose on a spreadsheet of many thousands of lines of feedback via advanced data analysis and let it work out the sentiment expressed in each, giving you quantitative results from qualitative data that would normally require human grunt work. (In other words, how many of these social media comments on the latest issue of *PC Pro* are positive?)

Chain of thought prompting is another technique that can help avoid errors. Here you're asking the AI to think through its answers step-by-step, to show its working, if you like. For example, you might ask:

I've been offered two loans, each for £100,000, repayable over three years.

The loan from Barclays has a 4.5% APR and an arrangement fee of £500.

The loan from Santander has a 4.9% APR and an arrangement fee of £600.

Which has the cheapest overall cost? Think step-by-step and show your working.

When we first entered this into ChatGPT Plus, it gave us a long set of workings, but that revealed its

answer was based on annual payments, and not the monthly payment terms that most loans are based on. To confirm, we asked:

Are you assuming payments are made monthly?

It then went off and calculated the correct figures, answering that the Barclays loan would be around £800 cheaper over the three-year term (it provided more detailed answers than this).

There are a few key lessons, then:

1 Be as precise as possible with your initial prompt (for example, using "APR" rather than just "interest rate").

2 Get the AI to show its working, so that you've got a better chance of spotting mistakes, misassumptions or hallucinations (stuff it's made up).

3 Challenge the AI on its methodology, so that you can be as sure as possible that the answers you're getting are correct.

WHAT ARE GPTs?

OpenAI, ChatGPT, GPT-4, GPT... you almost need an AI assistant to stay on top of the many confusing terms that the AI industry generates. Just to clear things up: OpenAI is the company that created ChatGPT, the infamous chatbot that's generated more column inches than Elon Musk over the past year. (Heck, it's probably written a fair few of those column inches itself.) ChatGPT is partly based on the GPT-4 large language model (LLM), which OpenAI released in 2023. And a GPT is effectively a mini-version of ChatGPT, dedicated to a specific task, such as helping you plan a gap year or how to use a piece of software (see our step-by-step guide on p30).

You don't need any coding skills to create a GPT. They can be created using plain English commands given to ChatGPT. That doesn't mean there aren't particular skills and techniques you can apply to getting the best out of them or training them better, as we reveal in our step-by-step guide.

The key with GPTs is thinking of a very specific task that could benefit

from AI assistance. It might be helping you to formulate your company's annual report or buffing your Python 3.12 skills, but the more specific the better.

It's also worth noting that you can upload files or documents to GPTs to help with their training. Let's say, for example, you've treated yourself to a Canon EOS R50 camera and want to learn how to better use its numerous features and functions. You can upload the PDF of the camera's official manual to a GPT and then use your AI assistant to guide you when you want to find out how to change the flash settings or activate the self-timer. That means the AI is less reliant on the unreliable information it might otherwise source online.

At a more advanced level, you can even connect a GPT to a third-party service such as Zapier and use it to query other services, such as your Google Calendar. We haven't got space to go into setting up these quite advanced features here, but it's something we may return to in a future issue. Zapier has advice on how to set these up at **zapier.com/blog/gpt-assistant**.

RIGHT Meet the new boss, same as the old boss: Sam Altman, OpenAI CEO

6 different things you can do with GPTs

1 Follow a brand guide
If your company has a brand guide that must be applied to all of your internal and external comms, you can upload the guide to a GPT and then paste in documents, assets and suchlike before they're published to check that they comply with the brand guide. The AI can even rewrite the copy for you, although proceed with caution here.

2 Help with homework
If you've long since forgotten the difference between an abstract noun and a concrete noun, or are a bit fuzzy

help you learn and strategise in a particular game. Previous answers are always stored, so you can use the GPT as a reference library.

5 Deliver new data insights
Finally that spreadsheet you've kept of your weather station readings for the past 12 years is going to come in useful! GPTs can be used to generate data insights and visualisations for specific projects. Tell the GPT what kind of analysis or graphical output you require, regularly feed it new data, and watch it do the leg work.

ABOVE Don't get mad with irate customers – use a GPT to get even

LEFT A GPT is likely to be more helpful with the kids' homework than you

BELOW GPTs can create stunning AI artwork using the DALLE 3 engine

6 Handle rude customers
If you've ever been on the receiving end of rude emails from stroppy readers – sorry, I mean customers – then it can be hard to resist the temptation to fire a stream of invective back. However, you can let the AI do it for you. Train the GPT on the kind of conciliatory tone you want to set in professional replies, tell it what you want to say to the customer in bullet point form, and let the AI add the calming balm.

on the purpose of a coordinating conjunction, you might struggle to help the kids with their English homework. Instead, create a GPT, ask it to explain everything in terms a 12-year-old can grasp, and fire questions into your new AI assistant to overcome the homework hurdles.

3 Generate website images
Need some stock imagery for a website you're creating? GPTs can create AI art, too, using the DALLE 3 engine, which has come on in leaps and bounds recently. Tell the GPT what kind of website it is, the artistic style you prefer, what to avoid, and it should be much easier than trying to generate unique images every time with DALLE 3 alone.

4 Master complex games
It's easy to get lost in complex video games such as *Crusader Kings III* or *Civilization VI*, not really understanding what's going on. On a less techie bent, maybe you've always fancied learning bridge or chess, but can't make head nor tail of those symbols they publish in the newspaper puzzles. A GPT can

Finally that spreadsheet you've kept of your weather station readings for the past 12 years is going to come in useful!

CREATE A GPT: Step by step

Here we're going to show you how to create a GPT that acts as a virtual assistant for Adobe Photoshop, providing step-by-step instructions on how to perform complicated tasks. It's just one of many different types of GPT you can create, and the guide below is not intended to be definitive – you'll need to mould your own GPTs to your particular needs. However, our guide will give you tips on how to create GPTs, how to test they're working properly, how to provide feedback when they're not, and how to tweak their performance as you go along.

1 CREATE A NEW GPT

To create a GPT you'll need to be a GPT Plus subscriber ($20 per month at the time of writing). Once you're in the ChatGPT Plus interface, hit the Explore button that should appear in the top left-hand corner of the screen and you should see a selection of GPTs already created by OpenAI to give you a flavour of the kind of tasks they can perform. To make your own, hit the Create a GPT button at the top of the screen.
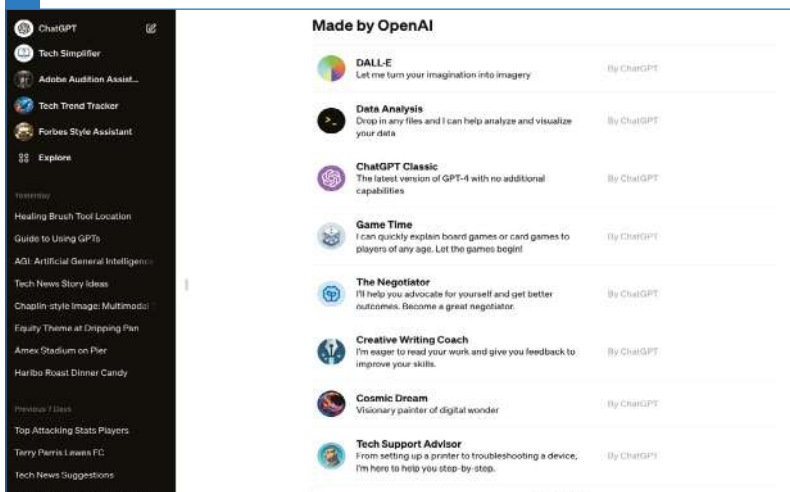
2 DEFINE THE GPT'S ROLE

When you create a GPT, you interact with the chatbot on the left, telling it what you want, while in the right-hand pane it builds a demo of your GPT that you can eventually test. First, ChatGPT will ask what you want the GPT to do and here it pays to be succinct but specific. For example, we tell ChatGPT that we want to build an assistant for "Adobe Photoshop 2024", not just "Photoshop", so it knows we want answers tailored to that version. We could have been even more specific and said for Windows rather than Mac, for example, so that keyboard shortcut instructions were issued correctly, but we'll show you how to make such changes later.
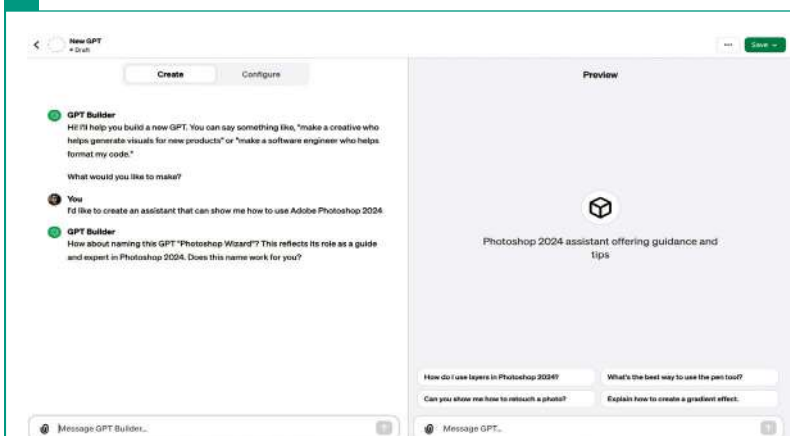
3 GIVE IT A NAME AND ICON

ChatGPT will automatically suggest a name for your new GPT and even use the DALLE 3 image-generation engine to design an icon for it as well. If you don't like the name it suggests, you can simply write your own. If the icon's naff, you can ask it to have another go, or describe what you'd like the icon to contain.
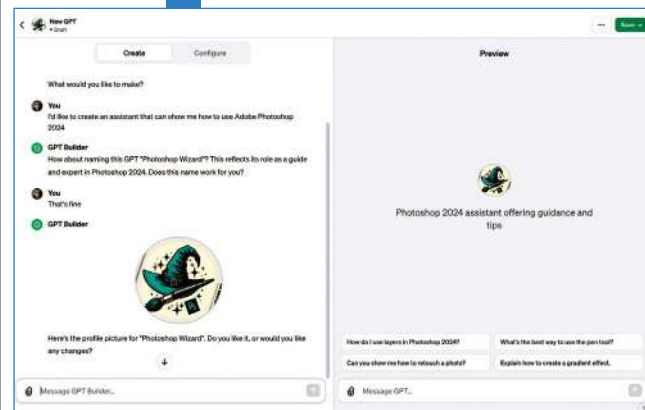
4 GIVE YOUR GPT DIRECTION

Now we begin to define how your GPT will act and respond. ChatGPT will ask you a series of questions about what you specifically want the GPT to do, how it should answer your questions and even which type of personality the chatbot should adopt. This is the time to start drilling down into specifics and being very clear about what you want the GPT to do and, just as importantly, not do. Below, for example, it's asking for "the type" of humour we enjoy and we nip that in the bud quickly. We want instructions on how to use Photoshop, not a GPT-driven Michael McIntyre.

This section can be quite confusing as the GPT often asks the next question before you've finished answering the previous one. Don't get flustered. Just keep answering them one at a time and feel free to add extra instructions beyond what it's asking for.
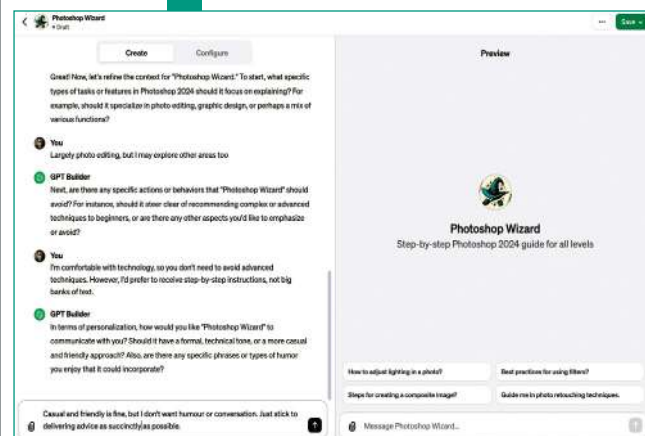
5 START TESTING

Once you've laid down the basic ground rules for your GPT, it's time to start testing in the "playground" pane on the right-hand side. Ask the GPT a question in that right-hand pane, not the left! It's helpful at this stage if it's something you already know the answer to, as it gives you a feel for whether the GPT is looking in the right sort of places for information or whether it needs more guidance. Answers should appear promptly, and if you don't like the tone of the answers, it's not explaining clearly enough, or it's dumbing down, provide feedback in the left-hand pane so that ChatGPT can make adjustments to your GPT's output.
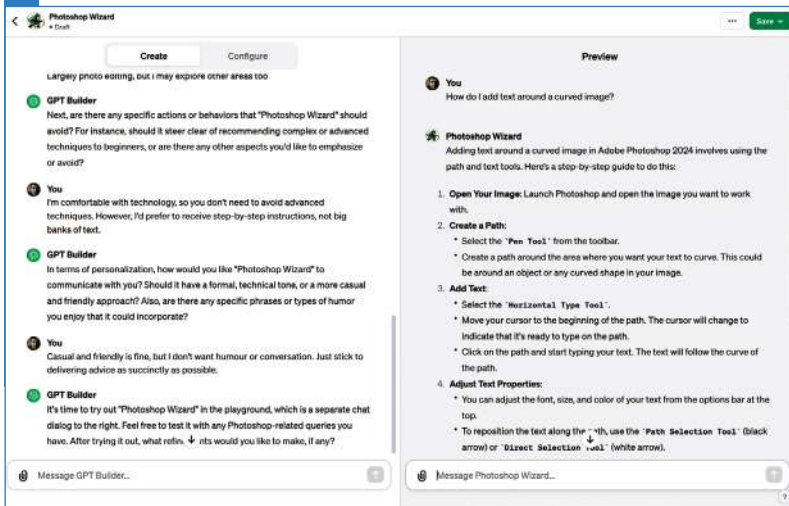
> Make sure you provide feedback on the left, so the GPT knows when it's getting stuff right as well as when it's wrong

6 CORRECT BAD BEHAVIOUR

As we were building our Photoshop Wizard, we pushed our luck a bit and asked ChatGPT if it would be possible to include screenshots with its answers to help us find the right icons. This is where we ran into one of ChatGPT's (and AI in general's) big problems: it makes stuff up. Literally, in this case. Instead of supplying screenshots it supplied a DALLE-generated image that showed a mangled Photoshop-like interface, which was about as much use as a thesaurus to a bricklayer. Make sure to put ChatGPT straight when it veers down the wrong path. In this case, we told it explicitly we don't want to see screenshots in any future solutions. Again, make sure these instructions are submitted in the left-hand pane, not the right, or your GPT won't learn.
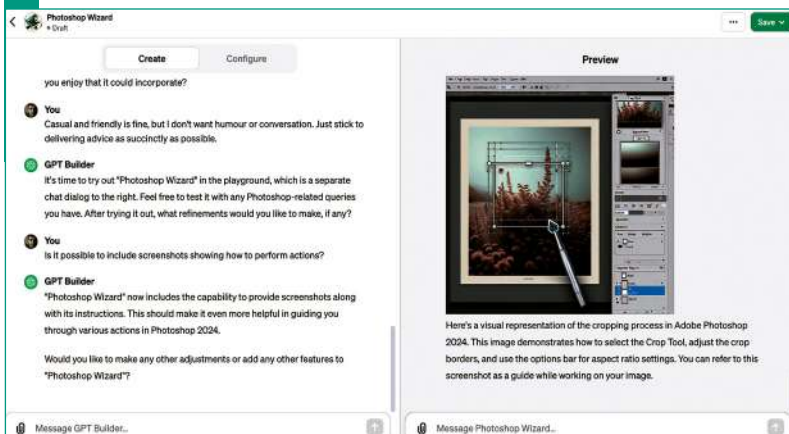
7 ASK FOLLOW-UP QUESTIONS

Don't just test your GPT with a series of one-off questions. Ask follow-ups to see how it reacts and, again, be prepared to issue corrections or advice if it veers off course. In this example, we'd followed our GPT's instructions on how to replace a sky in an image, but when we went to save the image it wouldn't let us save in the JPG format, even after flattening the layers (which is normally the cause of such problems). So we asked the GPT for follow-up advice and it delivered. The second suggestion on bit depth was actually the cause of the problem. Make sure you provide feedback in the left-hand pane, so the GPT knows when it's getting stuff right as well as when it's wrong.
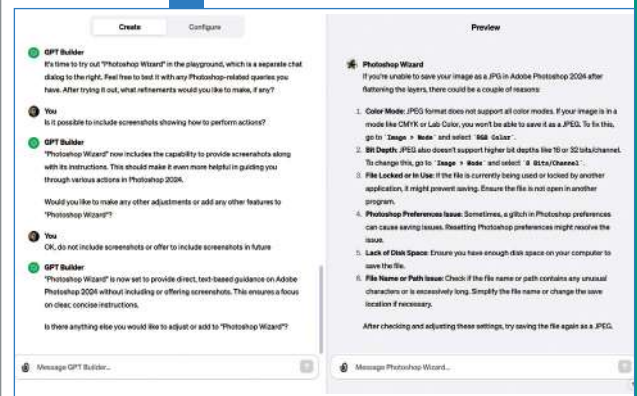
8 ADD FILES TO HELP TRAINING

If you want to add your own data to train the GPT with, you can do so by clicking the Configure tab in the left-hand pane and selecting Upload Files. You can upload a variety of files including PDFs, Excel workbooks, Word documents, HTML files and more. If, for example, your company has brand guidelines, you could upload them here and create a GPT that ensured all of your marketing materials followed the rules. In our Photoshop Wizard example, we could upload a PDF software manual (if Adobe still produced such a thing) to help steer the GPT in the right direction. Back in the chat pane, you can also steer your GPT to particular websites if you think they're a good source of information for your needs. GPTs have live access to the web, so they fetch the latest updates.
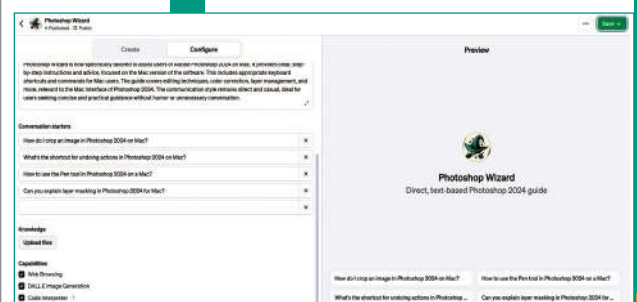
9 TWEAK YOUR STARTERS FOR TEN

Every GPT has four default questions available above the prompt bar, which you can edit from the Configure menu. This is a good place to enter a question you might ask repeatedly, saving you from having to type it afresh each time. For example, if you've created a GPT designed to scour news sites for mentions of your brand, you might have a default conversation starter that says: "Check the news sites for any new mentions of ABC Laptops today." Simply delete these Conversation Starters if they're never going to be of any use.
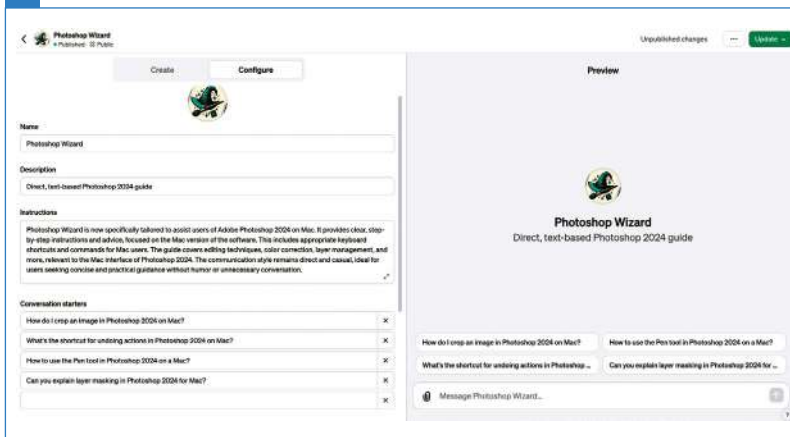
10 PUT THE GPT LIVE

Once you've given the GPT a thorough test and you're relatively satisfied that it's behaving itself, then it's time to publish. Don't worry if you've not got everything 100% nailed down at this point, as you can still tweak and reconfigure the GPT once it's live. When you click that Save button in the top right-hand corner, you're given three publishing options: Only Me, Only People With A Link and Public. Only Me means only you'll have access to the GPT, which is ideal for GPTs you might have trained on confidential data (note – if you're using GPTs for business, you really do need to interrogate the OpenAI privacy policies carefully and never upload sensitive information such as customer contact details to ChatGPT). Only People With A Link means you can share the GPT with other ChatGPT Plus subscribers. And Public means the GPT could appear in a forthcoming GPT Store that wasn't available at the time of writing, but might even let you earn revenue from other people buying access to your GPT.

11 EDIT YOUR GPT

If you find you want to tweak your GPT's behaviour once it's live, it's easy to do so. Click to open the GPT from the ChatGPT sidebar on the left and then click Edit GPT from the dropdown menu that appears. Now you're back in the familiar setup interface, where you can issue commands on the left and test the GPT on the right. Here, for example, we could specify we want our GPT to issue instructions for the Mac version of Photoshop and it will adjust its behaviour accordingly. You can also upload more files here, if you want to add new data to help train the GPT. The key thing here is to press the Update button in the top-right-hand corner once you've finished editing. Even if the chatbot asks you if there's anything more you want to change and you reply "no", it won't save any changes unless you press Update, which is an easy mistake to make.

12 KEEP PUSHING IT

Even once you've got your GPT published, keep pushing and prodding it, exploring its capabilities. For example, it's easy to forget that you can query your GPT with uploaded files as well as upload files for training. Here, for example, we ask our GPT to give us instructions on how to copy a style of a portrait by uploading the image we want to copy and one we want to convert. The GPT understands what we're asking and issues a largely accurate step-by-step answer that delivered a decent result. Keep exploring ways you can push the boundaries of your own creations.

Don't worry if you've not got everything 100% nailed down, as you can tweak and reconfigure the GPT once it's live

HOW WE CREATE THE *PC PRO* PODCAST IMAGES

Regular *PC Pro* podcast listeners might know that Barry sometimes produces AI-generated images of that week's podcast guests ahead of the show. We've had Jon Honeyball as a *GTA V* character, editor Tim as a Lego figure, and Lee Grant as a wonderfully oddball Pixar character, among many other themes.

Readers have occasionally pinged us on social media and asked how they're created (thanks, mum), so here's a quick guide on how to get AI images of people you might know.

To create these images, Barry uses the Midjourney AI service. Midjourney allows you to upload your own images and use them as reference images. ChatGPT Plus/DALLE 3 also allows you to do this now, but we seem to get consistently better results from Midjourney.

The key to success is the quality of the reference image. You ideally want a high-definition portrait shot where the person's head and shoulders fill the frame, so the AI can ingest as much as facial detail as possible.

To get going, feed Midjourney a very basic prompt of what you're looking for. So, for a Pixar movie character, for example, you'd enter the following prompt into Midjourney's Discord interface:

/imagine http://www.referenceimage.com as a Pixar movie character

(The web address here is a substitute for a link to the reference image. You can drag an image into Discord's chat interface and upload it to get a unique link for an image you've saved locally.)

Sometimes you'll strike gold with a prompt as simple as this. At other times, you might need to do extra legwork.

Often, being more descriptive can help refine an image. So, for our Pixar image you might embellish the prompt with details such as:

/imagine http://www.referenceimage.com as a Pixar-style character, vibrant colours, smooth textures, exaggerated facial features, friendly expression --style cartoon

The key addition here is the "style" parameter, denoted by the double-dash before the word. This reaffirms to the AI that we're definitely looking for a cartoon-style image.

Finally, if a generated image is close but not quite right, or some weird glitch afflicts the image (such as a hand with only four fingers), the Vary buttons that appear under upscaled images are your friend. Vary (Strong) is good for where the AI has got a strong likeness of your subject, but the image isn't quite there. Vary (Subtle) is good for fixing images with those annoying little glitches. ●

ABOVE The AI images we've generated for the *PC Pro* podcast have included Lego figures...

ABOVE ...As well as a frankly disturbing portrait of Jon Honeyball in *Grand Theft Auto*...
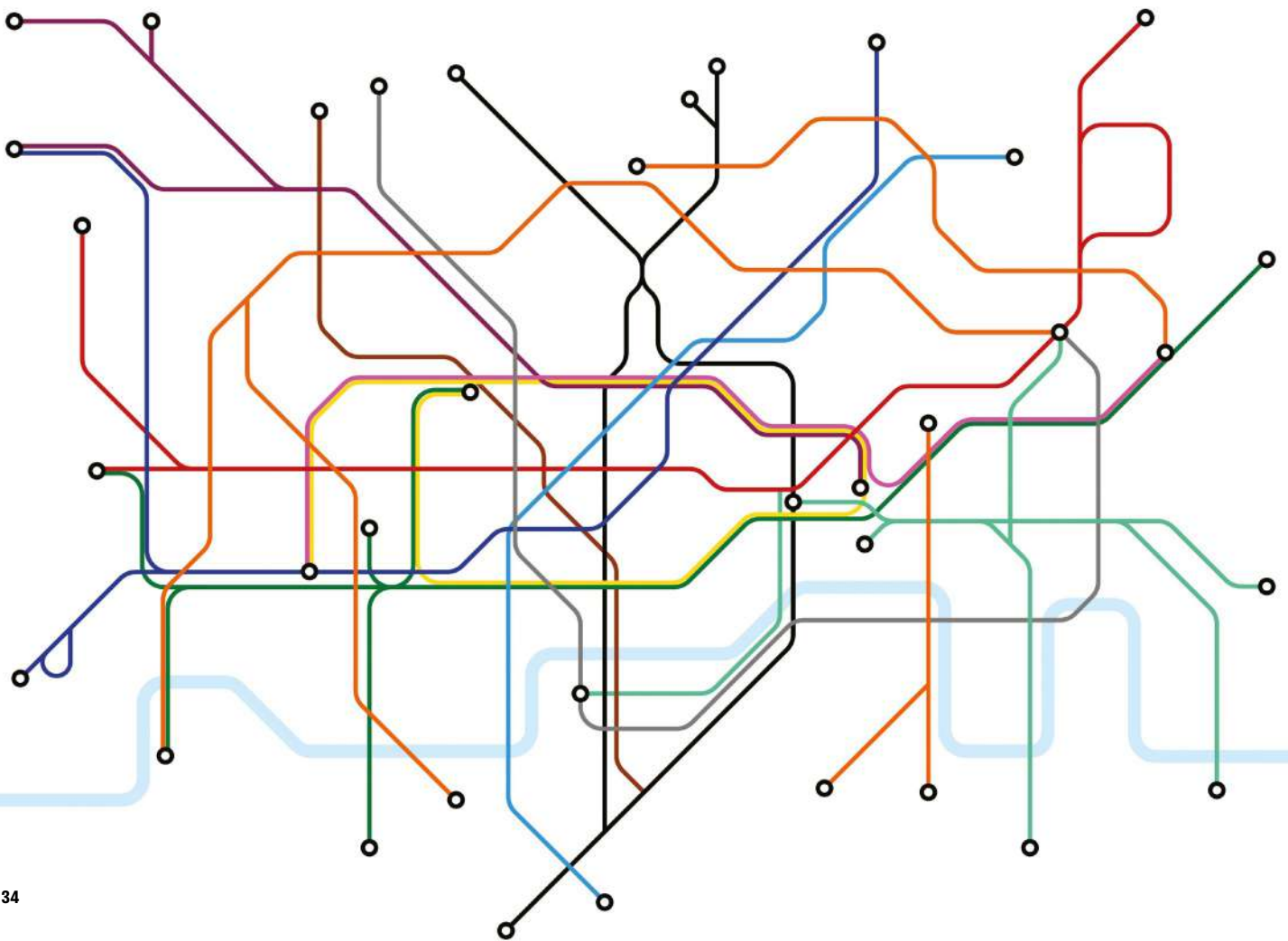

ABOVE ...And a less disturbing and altogether cuter image of Lee Grant as a Pixar character

THE WRONG TRACK?

How your mobile data keeps London moving

James O'Malley reveals the extraordinary way Transport for London uses mobile phone data to plan public transport

It's a well-known maxim in the technology industry that if you're not paying for the product, then you are the product. We get to use incredible services such as Gmail, Facebook and Twitter for free – and, in return, the big tech firms sell access to our eyeballs to advertisers.

But this isn't always the case. Sometimes, even when we pay for a service, we're also the product being sold.

For example, something that EE, O2 and Vodafone all do, but don't really like to shout about, is sell anonymised, aggregated data about our physical movements to local authorities, transit agencies and any other companies prepared to sign large enough cheques. And that's how I came to discover many of the really mad things that Transport for London (TfL) can figure out about us by using our location data, provided by the O2 mobile network.

Using the Freedom of Information Act, I've managed to obtain the Data Protection Impact Assessment and the Statement of Work for TfL's Project Edmond – which stands for Estimating Demand from Mobile

Network Data. It gives transport planners and policy makers an amazing quantity and quality of data on people's movements.

The way Edmond works is very clever. TfL isn't actually monitoring all of our phones all of the time, presumably because it knows that to do so would be hugely controversial.

Instead, it contracts with O2 to license data over shorter periods of time. For example, in 2023, it took data from "up to" 40 normal weekdays between the start of April and end of June, when nothing unusual was happening like school holidays or bank holidays.

This is an enormous dataset, with data from up to 25 million phones included. But Edmond isn't a mere pile of data; it's a model, where TfL has taken the data from O2 and performed clever maths to scale it up to estimate the movements of everyone in London over the age of 12.

Now that's dealt with that elephant in the corner, struggling to hide behind the curtains. Though it might be surprising to learn that O2 is selling data insights on its customers, it isn't selling personal data. What's being sold by O2 and licensed by TfL is aggregated, anonymised data. This means TfL can't see the movements of individual people, and everything is fully GDPR-compliant and above board – as you'd expect for a major corporation and a transport agency. In fact, according to the 2018 "Travel in London" report, any time the data suggests there were fewer than ten phones in a given statistical area, the data was automatically excluded so as to avoid inadvertently unmasking people based on their metadata.

So to be absolutely clear, there's no big scandal here. In fact, using this sort of data is increasingly routine for local authorities and others, to the extent that O2 even has a brand name for this line of its business: O2 Motion.

But that doesn't mean what's happening isn't interesting. In fact, I'm willing to bet that most people outside of the mobile industry are completely unaware their movement data is being used in this way.

Now let's get to the good stuff. What does all this data do for TfL, and what data do they have to play with?

Mapping people's travel

Because of the aforementioned privacy restrictions, they don't simply get dots on the map showing

them where everyone was. Instead, the data is broken down into hundreds of "Medium Super Output Areas (MSOAs)". This is a statistical standard that divides up the country into groups of between 2,000 and 6,000 homes.

Using the aggregated data from O2, TfL can see which areas of London people are travelling from and where they are travelling to – which is exactly the sort of information you might need if you were, for example,

Figure 5: Dwells in the mobile network data can be analysed to identify the home and work location of users

planning where to run buses or impose an Ultra-Low Emissions Zone that disincentivises car use.

It goes deeper. It's also possible to work out which parts of London are hosting the most international visitors, by looking at which MSOAs have the most phones using international roaming mode inside their boundaries. (Unsurprisingly, it appears the busiest areas for international visitors are the West End and Heathrow.)

Whether your SIM card is roaming is by no means the only thing that O2 knows about its users. In fact, because it has demographic data on its contract customers, it's possible to break down the demographics of people in each MSOA by gender and age, as well as the time of the day they were there.

It can tell whether you're male or female, whether you're a "resident", "worker" or "visitor". O2 doesn't only know where you are, it knows why you're there, too. How does it do this? By making some smart assumptions.

For example, it determines your home by looking at the place where you spend most evenings and nights during the prior month. It also figures out where you work based on where you spend working hours during weekdays. And according to the documents I've obtained, it appears that the latest 2023 modelling will

also be figuring out when people are specifically travelling to educational establishments such as schools and universities, too.

Predicting passenger movements

So TfL isn't just able to figure out where people are travelling to and from, but why they are travelling. And, amazingly, the model gets even smarter than this.

The most impressive thing about the Edmond model is that it can seemingly predict by what means you're travelling – whether by foot, bike, car, train, bus or even lorry.

This is a really hard question from a technical perspective. The obvious way to do this would be for O2 to look at the speed at which your dot on the map is moving and the route on which it's travelling. That way, it could conceivably match you up to known bus routes or railway lines. In fact, this is how railway travellers are identified – they look at where clusters of users appear to be moving together, as indicative of groups of people inside a train carriage.

But on London's busy streets, traffic will sometimes crawl to walking pace. And besides, how can they figure out if you're in a car, taxi or bus? Or even on a bike? How can it tell the difference?

I've seen other devices attempt to figure this out before. My Apple Watch will ask me if I'm cycling when it detects that I'm moving at cycle-like speeds and my heart rate is elevated. And Google Maps will sometimes ask me to rate my bus journey if it detects that I've just checked when the next bus is coming and have then travelled along the route of that bus. But both of these things require access to either the contents of my phone or a heart-rate monitor, neither of which O2 has knowledge of.

Instead, the Edmond model goes into its mind palace and reasons an answer using pure logic, by leaning on TfL's Public Transport Accessibility Level (PTAL) data. PTAL is a map of London, divided into thousands of individual squares, each of which has been given a score for how accessible public transport is. Scores range from zero (the bits of countryside that are still technically in Greater London) to 6B – imagine you're standing just outside Kings Cross station with a half a dozen tube lines, national rail and countless buses to choose from.

Because it knows where you're travelling and the route you're taking, Edmond looks at the PTAL scores for the different locations you hit, and makes a prediction on the means by which you're travelling, based on which transport options were available to you. TfL knows this works, because it's validated these predictions against data collected by its more traditional London Travel Demand Survey, which is posted to households and filled in by people with clipboards. And the data all lines up.

From some aggregated dots on the map, the time of day and demographic data, TfL has built up a hugely detailed picture of how people are moving around London.

People don't like it

Edmond data is, unsurprisingly, widely used internally. It's one of the key tools used to forecast cross-river traffic for the controversial Silvertown Tunnel, which is currently under construction in East London. And it has also been instrumental in forecasting traffic patterns when rolling out the even more controversial ultra low-emissions zone scheme.

More generally, it also feeds data into TfL's other, even bigger strategic models, such as MoTiON. This incorporates mobile data, taps from the Oyster cards that people use to travel on the Underground, real-time bus data, public bicycle hires and even data from the cycling app Strava to model how London travels. Which I guess is what it takes if you want to keep a city of nine million people moving.

It's all astonishingly impressive from a technology point of view, but the privacy implications weird me out. And I know I'm not the only one.

I'm not really a scoop-getting journalist. I'm more of a "I spoke to some experts and they agree it's complicated" guy. But back in 2017,

I broke the story of what TfL had learned from tracking phones on the Tube network using Wi-Fi. The story is similar to this one: by using Wi-Fi pings from our phones, TfL can plot how we're moving around the Tube network, even if we haven't connected to the Tube Wi-Fi network.

One document I obtained for that story also contained the results of a focus-group study conducted for TfL, basically testing the attitudes of the public to different types of mobile data tracking. Wi-Fi tracking was actually received quite well. People understood that it helped TfL manage the Tube network and work out how crowded trains are – data that can today be seen by passengers in transport apps. And the data collection was perceived as relatively transparent, presumably because tracking can be signposted inside stations. It's also relatively easy to opt out by switching off the Wi-Fi on your phone.

By contrast, taking data direct from the mobile networks was more poorly received – with people

setting up a system that collects data in real-time around the clock. I can't really fault TfL for using the data. The fact that O2 is willing to sell these anonymised insights must be irresistible if you're managing a transport system, especially in a city as complicated as London.

What I am more sceptical of is the fact that this data is being collected and sold by the phone networks in the first place, because think for a moment about what they need to collect to make it work. It means that somewhere inside my phone network's databases are my movements for at least the past month – revealing everywhere I've been, who was in the same place as me at the same time, and just how many times I've shamefully stopped in at Burger King on the way home because I can't be bothered to cook.

Although TfL and the networks' customers only see the data in an anonymised, aggregated form, that's not true of the networks, who must store and analyse my actual data to make it useful.

a certain point, the civil liberties arguments become important.

One useful gut-check of any new technology is to imagine how it might be used by a bad actor. You don't have to think too hard to imagine how such tracking technology could be misused by an authoritarian if they were to come to power. There is definitely potential for what Edward Snowden calls "turnkey tyranny".

The question for policy makers and voters, then, is how do we balance the

utility of the data analytics that the networks are selling, and the potential risks that we're building tools that could conceivably be used as the tools of oppression?

And as an unsatisfying ending to this piece, I'm not sure in the specific case of Edmond where the balance lies. It's definitely a strong case for why we should do our best to build strong institutions to protect our democracy, so that we can more safely take advantage of new technology, and build a more functional society, without any of our rights feeling threatened.

But even if we decide that the networks closely tracking us is fine because it's useful, we should be careful to maintain a healthy scepticism, too. And that starts from actually knowing it is a thing that happens. So at least, having now reached the end of this article, you and a few thousand other people will know about it. If only Edmond could also figure out what we should do with this information. ●

International visitor locations of stay

Average number of overnight stays per day
- >8,000
- 4,000 to 8,000
- 2,000 to 4,000
- 1,000 to 2,000
- <1,000
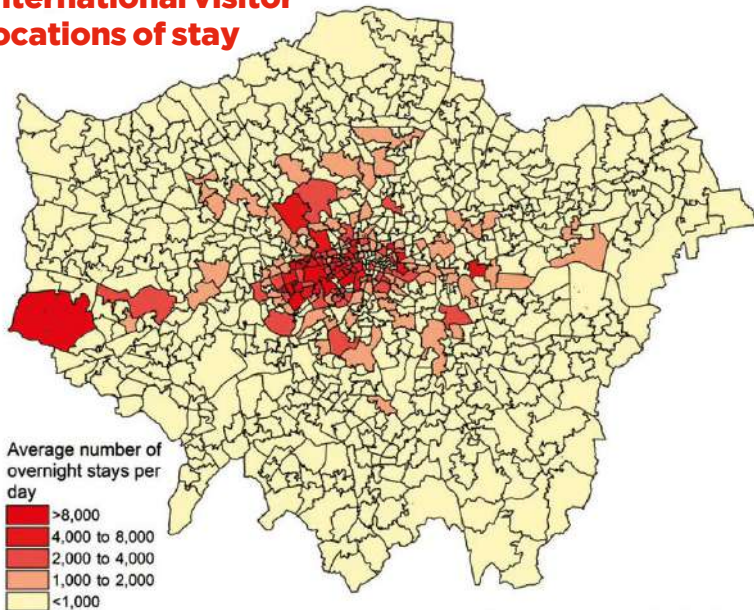
Source: Strategic Analysis, TfL City Planning.

unsure why it was being done, or how they would benefit. I think this reaction from the public is pretty understandable. It is literally the case that the major phone networks are recording our movements and building up a surprisingly detailed picture of the places we sleep, work and hang out.

To its credit, TfL does appear to have approached the data in the most minimising and proportionate way possible – by taking a small sample of anonymised data, and using it to build a model, instead of

Arguably, this is a good thing. You can imagine how, for example, it could make it easier for the authorities to hunt down a terrorist on the run or a missing child. Slightly further down the slippery slope, you can imagine how this same tech could also be used by the security services to find everyone who attended a protest over the weekend, and within seconds tell them not just where attendees live, but where they are right now.

Whether that would be proportionate or not, I'm not sure. But what's obviously true is that at

BACK UP YOUR FILES
HASSLE-FREE

We all know our precious files need protection, but backing up can seem like a tedious chore. It doesn't have to be that way: **Nik Rawlinson** has no-fuss, hands-off backup options for all your devices

BACKING UP **WINDOWS FILES**

There are countless backup suites for Windows, and we certainly wouldn't advise against using them. But if you don't have a proper backup system in place, an occasional drag-and-drop copy provides some quick and easy peace of mind.

Naturally, you shouldn't keep your backups on the same drive as the originals. Consider investing in an external drive: at the time of writing, you can pick up a Crucial X6 1TB portable SSD for £46, or a 1TB Kingston DataTraveler Max USB flash drive for £75.

Indeed, once you've got your backup drive, there's no need to restrict yourself to manual copies. Windows 10 and 11 include the underappreciated File History feature (introduced in Windows 8), which runs in the background and automatically backs up your personal data to an external drive or network location. You won't find it in the Settings app, though: you have to open the legacy Control Panel app (search for it in the Start menu), then select "Save backup copies of your files with File History".

When File History is enabled, your local

Desktop, Documents, Downloads, Music, Pictures and Videos folders will all be regularly backed up, along with anything else contained in a user library. By default, copies are made every hour and kept forever, or until your destination runs out of space. To add an extra folder to your backup set, just right-click it in the File Explorer, select "Show more options" from the context menu, then select "Include in library…".

When you want to restore files, Windows brings up a handy Explorer-type interface showing all of your backed-up files and folders. Arrow controls at the bottom let you step backwards and forwards in time, and the big green button restores selected items.

You'll notice that the whole File History experience has a distinctly retro look. The fact that Microsoft hasn't updated it for Windows 11 suggests that it's on its way out. For now, though, it remains one of the easiest ways to protect your data. We've just one warning – don't use the same backup drive or network location with multiple computers, as files from one could get overwritten by copies from the other.
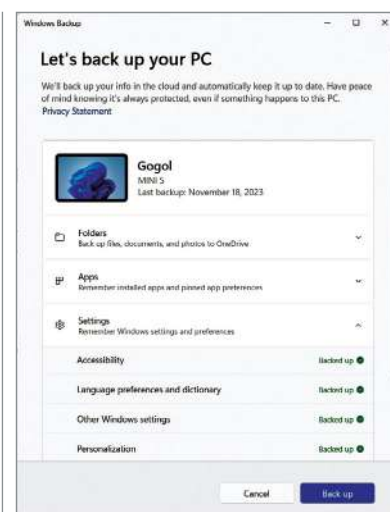
BACKING UP TO THE CLOUD

One plausible reason for the defocusing of File History is that Microsoft wants you to use OneDrive for your backups instead. This isn't a bad idea, since every Microsoft account gets 5GB of OneDrive storage for free – and it's easier than ever to manage thanks to Windows Backup, included in the latest editions of Windows 10 and 11.

You can access Windows Backup directly from the Start menu. It opens
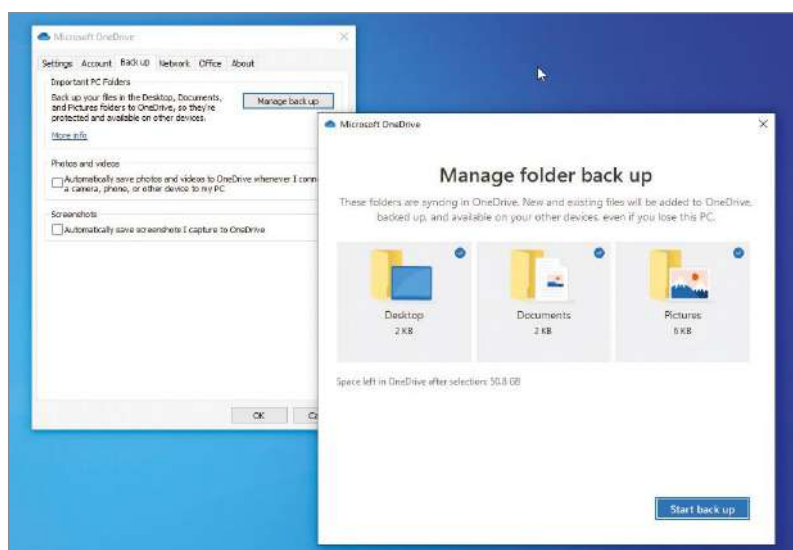
LEFT The OneDrive app lets you specify which folders should be backed up

with a view of which items will be backed up; note that "Apps" here refers only to apps downloaded from the Microsoft Store, and doesn't cover programs you've installed yourself.

If you're already using OneDrive then some item types may already be selected. To customise what's backed up, open Settings and click Accounts, followed by "Windows backup", then turn off any options you don't want. If you're using Windows 10, you can specify which folders should be backed up inside the OneDrive app by opening the settings window and switching to the "Back up" tab.

With a regular personal OneDrive account, up to 25 previous versions of

each item will be saved. These don't count against your storage quota, and you can browse and restore them using the Version History feature, either from the context menu in the File Explorer or the OneDrive website.

BELOW You can create a system image from the old Control Panel

NATURALLY, YOU SHOULDN'T KEEP YOUR BACKUPS ON THE SAME DRIVE AS THE ORIGINALS

CREATING A SYSTEM IMAGE

If you want to back up your entire PC system – including all applications and Windows settings – you can create a full system image using another legacy tool. To find it, open the Control Panel and click "Backup and Restore (Windows 7)" on the home screen. Then, click "Create a system image" in the sidebar and select where you want to save your image to. Click "Next" to see a summary of your options, then "Start backup" to begin the process.

To automatically create periodic system images, click "Set up backup" in the main window, and again pick a destination for your backups. You'll then be prompted to select which items you want to back up. It's up to you whether to include personal files in this backup job or not; the important part is to leave the box ticked at the bottom to create a system image.

Click Next to review your settings. By default, a new image will be created every Sunday evening, but you can change this to suit your needs. You'll also see a warning that a system repair disc may be required to restore a system image. You can make one using the Recovery Drive app, which will create a bootable external drive to use if you need to carry out a full recovery. ➡

BACKING UP **MACOS**

Backing up on macOS couldn't be simpler: the built-in Time Machine feature is the nearest thing you'll find on any platform to a true click-and-forget backup system.

Time Machine backs up your files in the background, storing changes to an external drive or network location until it gets full. Actively used files are backed up hourly, with daily backups for anything used in the last week and weekly copies for everything else. When the drive is full, the oldest archives are removed to make space for new content – so if you want to keep backups indefinitely, you'll need a secondary backup solution.

interface doesn't offer the full range of Finder features, it still supports Quick Look, so you can tap the spacebar to preview a file before restoring it.

If you're backing up to a network location you can also get at your files by locating the "sparsebundle" file on your NAS and double-clicking to mount it as a virtual drive. You can then browse all backed-up files by date, and copy anything you want to restore to a local location.

Time Machine doesn't just back up your files: it also covers applications and OS settings, so if you're moving from an old Mac to a new one, you can restore your whole system from a Time Machine backup using the macOS Migration Assistant tool.

You can also use Time Machine with multiple destinations, for extra protection against hardware failures or system errors. If you're using multiple external drives, Time Machine will remember each one, and each time you attach one it will automatically back up everything that's changed since the last time it saw that drive.

BELOW By default, Time Machine backs up changed files every hour
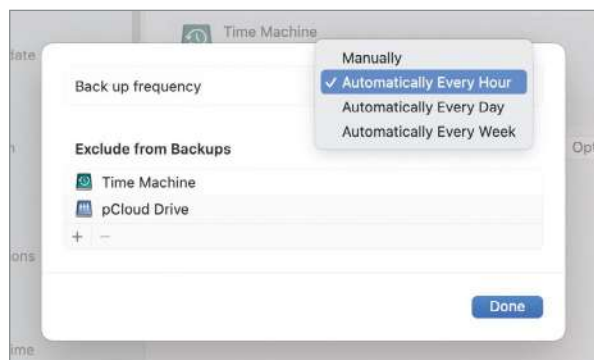
Turn on Time Machine from its page in the macOS Settings app. You can select any external storage device as your backup destination (be warned that it will be erased); if you want to back up to a NAS appliance you may need to manually enable Time Machine services before it becomes available as a backup destination.

Recovering files from Time Machine is as easy as clicking the Time Machine icon on the macOS menu bar and clicking "Browse Time Machine Backups". You can browse any folder and move forwards and backwards through time either by clicking the up and down arrows or using the timeline at the side of the screen. Although the Time Machine

BACKING UP **LINUX MACHINES**

It's in the nature of Linux that there's no single standard backup solution – but if you're using the Gnome desktop you'll probably have access to a user-friendly app called Déjà Dup Backups. Otherwise, you can install it from your distribution's software store, Flathub (**tinyurl.com/ 353flathub**), or from Snap Store (**tinyurl.com/353snapcraft**).

Déjà Dup Backups is very simple to set up. To get started, open the application, click the "hamburger" menu and select Preferences. Click Location, and select your backup destination – this can be a local folder, a network share or Google Drive for convenient offsite storage.

You can now switch to the Folders tab and select which directories you want to protect, before moving to the General tab to specify how long archives should be retained for. Click the switch next to Back Up Automatically, choose either Daily or Weekly from the Back Up Frequency menu, and relax in the knowledge that your files are protected.
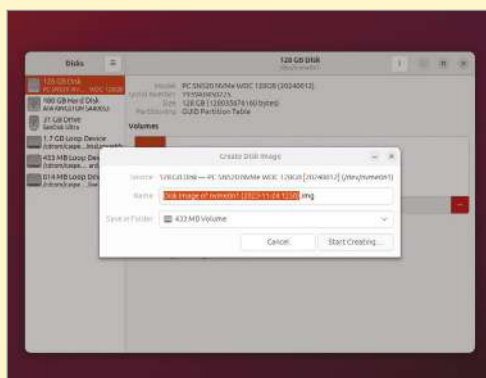
ABOVE Give your image a logical name so you can identify it in future

ABOVE RIGHT Restoring from a disk image overwrites all existing data

FULL LINUX SYSTEM BACKUPS
The easiest way to make a complete backup of your Linux system is by creating a disk image. Again, there are lots of different ways of doing this; we backed up our system by booting from a USB flash drive containing a live version of Ubuntu (available from **ubuntu.com/ download**), then used the Disks tool to image our main system drive. Booting from the flash drive ensured
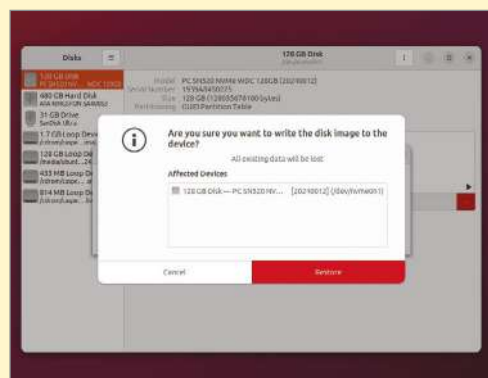
that the system files on our internal drive weren't in use, and were available to be backed up.

If we ever need to restore our system from the disk image, we can once again boot into the live environment, launch Disks, select the target drive and, this time, select "Restore Disk Image…". Bear in mind, however, that this operation will overwrite the entire drive, reverting all your personal folders to the state they were in when the image was created.

BACKING UP PHONES AND TABLETS

So far we've concentrated on PCs and laptops, but we're increasingly using our phones – and, to a lesser extent, tablets – both to capture our lives and keep it safe. But is it really safe if you're sending data to a cloud service, which you hope will last your lifetime but may not?

We don't think so, which is why we show how to take back control of the data on your mobile devices, no matter what the OS.

BACKING UP ANDROID DEVICES

Android devices automatically back up your data in Google Drive and Google Photos. To check your backup settings, open Settings and tap Google, followed by Backup. Make sure Backup by Google One is switched on; optionally, tap "Back up now" if you want to perform an immediate backup. If you don't, your device will be automatically backed up over Wi-Fi when it's been idle and charging for two hours.

To check the backup settings for your photos, open the Android Photos app and tap your avatar at the top of the screen. Here, you'll see the status of your image backups, which should say "Backup complete". If you want to save space in your Google Account you can opt to save images in a compressed format that doesn't count against your quota. To do this, tap "Photos settings", then "Backup"; now tap "Backup quality" and switch from "Original quality" to "Storage saver".

If you want to back up your Android device to a PC rather than to the cloud, it's possible to drag and drop files in the Windows File Explorer – but the option that enables this is located in the Developer menu, which is hidden by default.

If the Developer menu isn't visible in your Settings app, you can make it
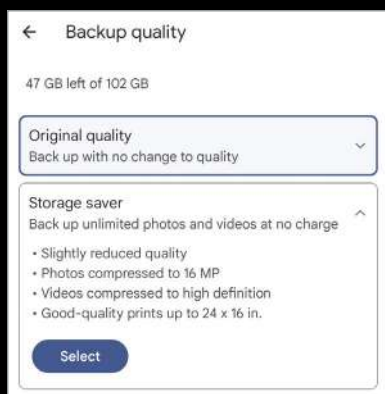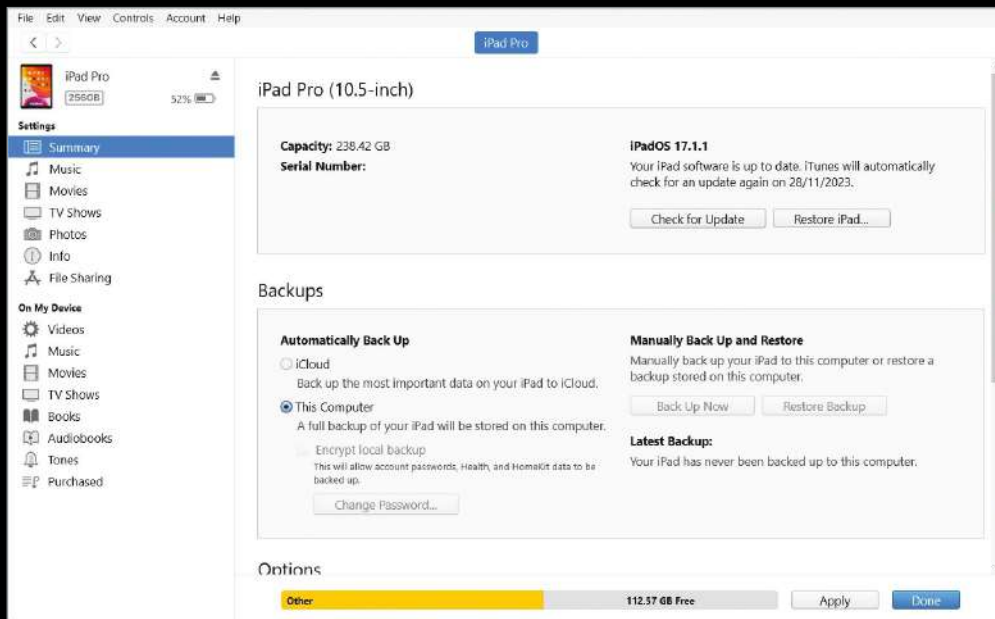
appear by opening the "About phone" page, then tapping "Build number" seven times. Once you've confirmed that you want to access the developer options, you can step back into the Settings and find the newly unlocked Developer menu.

Finally, to enable drag-and-drop copying, turn on the switch beside "USB debugging"; then tap "Default USB configuration" and pick "File transfer/Android Auto". Now when you connect your device to your computer you'll be able to browse and navigate its folders the same way you would a regular external drive.

AMAZON KINDLE FIRE

Although Amazon's Fire OS is based on Android, it handles backups in quite a different way. To enable automatic backups on a Kindle Fire device, open Settings and tap Device Options followed by "Backup & Restore"; then on the following screen flick the switch to enable Backup & Restore. Your device will now back up settings, bookmarks and installed apps to the cloud once

ABOVE Back up your Apple device either to iCloud or to your PC

ANDROID DEVICES AUTOMATICALLY BACK UP YOUR DATA IN GOOGLE DRIVE AND GOOGLE PHOTOS

BELOW Fire OS backs up your files in the background
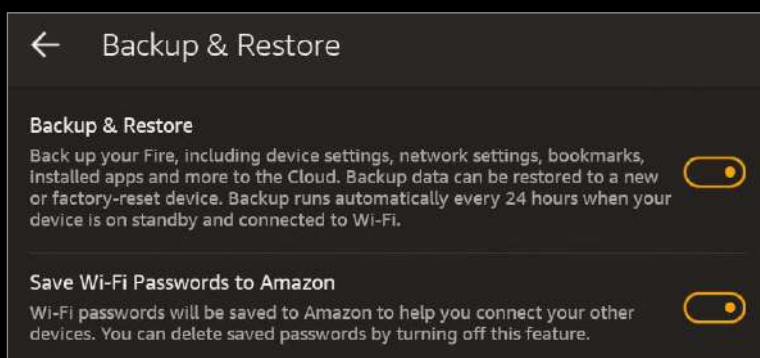
every 24 hours when the device is connected to Wi-Fi and in standby.

IPHONE AND IPAD

Apple devices automatically back up their local content to iCloud when they're locked and connected to Wi-Fi. To check that yours is doing this, open Settings and tap your name at the top of the screen. Tap iCloud, followed by iCloud Backup to view your settings; you can optionally also enable "Back Up Over Mobile Data" here.

To specify which apps' files should be included in the backup set, tap your device in the list, then use the switches beside each app (tap Show All Apps to view the full list). Note that photos are handled separately; to check that your snaps are protected, step back to the iCloud screen, tap Photos, and make sure the switch beside "Sync this iPhone" is on (to the right).

You can also back up your iPhone or iPad to a PC using iTunes for Windows (tinyurl.com/353itunes). Connect your mobile device to your computer using a USB cable, click the device button at the top of the iTunes window, then click This Computer in the Backups panel. To save yourself the hassle of manually connecting in future, scroll further down to the Options panel and tick "Sync this iPhone over Wi-Fi". ●

ABOVE You can compress your Google Photos to save space in the cloud

2FA
and beyond

If you want to protect your online accounts, two is the magic number. Darien Graham-Smith explores the different types of 2FA, and gives advice on the easiest ways to stay safe

No doubt you're already aware of two-factor authentication, or 2FA for short. It's an idea that arose in the 1990s, in recognition of the fact that simple password-based protection wasn't always sufficient for the growing number of online services.

Today, that's truer than ever. In the 21st century, almost every aspect of your personal life, from relationships to medical and financial records, is accessible over the internet – yet at the same time, passwords are being stolen left, right and centre. Try putting your details into **haveibeenpwned.com** and see how many times your own credentials have been stolen or leaked online. It's such a widespread issue that many security suites now include a tool that warns you when your passwords show up on the dark web.

Well, you might be thinking, no-one's yet hijacked my email or emptied my savings account. And if you're in that happy position, you probably have 2FA to thank.

What does 2FA mean?

There's a maxim in the security business that there are three ways to confirm your identity: with something you know, something you have or something you are. In practice these might translate to a password, a mobile phone or a fingerprint.

These methods aren't all equal – a fingerprint is hard to fake, whereas a password can be much more easily compromised. And if you ask me to believe that you're Joe Bloggs solely on the grounds that you have his phone, I might well be suspicious. But if more than one identity factor matches, there's a very strong chance that the person is who they say they are.

2FA therefore means requiring some additional proof of someone's identity, beyond a conventional password. It's also sometimes called MFA, or multi-factor authentication, because once you start down this road you can easily end up looking at more than two identifying properties – which of course isn't a bad thing.

How does it work?

As we've noted, hackers can get hold of usernames and passwords fairly easily. Normally you won't even know you've been compromised, as the

attackers won't hack you directly – they'll target the online sites and services you're logging into.

However, even if someone has your credentials, they won't be able to use them to log into a 2FA-enabled website. When the site sees that "you" are trying to connect from a new location or an unrecognised device, it will demand additional proof of the visitor's identity before letting them in. Some particularly sensitive services (such as banks) may require 2FA every time you log in or perform a transaction, even if there's nothing unusual about your activity.

The most common form of 2FA is a one-time passcode (OTP) sent to your phone via SMS (or via an automated phone call), which you type into the website to prove you're in possession of the phone. Opportunistic attackers have no way of accessing this code – not even if they've already hacked into your email, as it arrives via the mobile phone network rather than the internet. So they're stymied.

Be warned, though: fraudsters can try tricks to get you to reveal your OTP. A well-known scam is when someone advertises an item for sale or enquires about something you're selling; once you've made contact, they'll ask you to confirm an SMS code to prove your own identity. In reality, of course, they've triggered the sending of the

ABOVE Attackers need more than just a username or password to beat a 2FA-protected site

SMS code from your email provider or bank, and if you tell them what it is they can use it to log in as you.

A more sophisticated variant involves the scammer directing you to a fake website while triggering an OTP request from the real one. You think you're entering the code to access your own account, but in reality you're handing it straight to the attacker. The only defences are to never share codes, and always be wary of potentially fraudulent websites. Ideally you should be using a security suite or browser extension that will warn you if a site isn't what it appears to be.

In theory, there are other ways to defeat SMS-based 2FA codes. Someone could clone your SIM to get your messages sent to their phone, or they could contact your mobile provider posing as you, and ask to have your phone service redirected (a technique called SIM-swapping or SIM-jacking). However, these types of attack cost time and money, so you're unlikely to experience them unless you're a high-profile target.

Hardware 2FA

SMS OTPs are popular because they're free and easy to use, but as we've seen, they're not invulnerable against scammers. A more secure method of 2FA is hardware authentication.

This typically comes in the form of a USB device that plugs into a computer and digitally attests your identity when requested by a website or app. It does this via public-key cryptography, using an authentication standard maintained by the FIDO Alliance (**fidoalliance.org**) – an industry group focusing on easy, strong security (the name stands for "Fast ID Online"). FIDO members include Amazon,

> ## Normally you won't even know you've been compromised, as the attackers won't hack you directly

Apple, Google, Intel, Meta and Microsoft, plus financial heavyweights such as American Express, Bank of America, Mastercard and Visa.

As you'd hope, the various FIDO members all support hardware authentication for their own online services, as do numerous password managers. With hardware 2FA there's no opportunity for anyone to copy or spoof your proof of identity – it's sent over an encrypted stream directly to the requesting website – and there's no mucking about with copying and pasting codes. The only interaction is that you may need to unlock the device with a fingerprint or PIN code, and if you only have one key then you'll need to move it around to confirm your logins on different devices.

Probably the biggest downside of hardware 2FA is that you need to buy the hardware. The YubiKey range of authenticators starts at around £25 inc VAT (**yubico.com**) and includes NFC support, so you can authenticate yourself with a tap on a mobile device. As the technology is standards-based, there are plenty of other options as well, including devices from Feitian (**ftsafe.com**) and Thetis (**thetis.io**).

Authenticator apps

If you like the idea of cryptographic security but don't want to deal with a physical key, you can instead use an authenticator app on a smartphone or tablet. Popular options include Google Authenticator, Microsoft Authenticator, LastPass Authenticator... well, nobody said security experts have to be imaginative. Thanks to open standards, any service that supports authenticator logins can be used with any app, so you can try a few out and use whichever one you like most.

On the remote side, each service will have its own process for enabling authenticator access, but with a little

When you log into a system that uses passkeys, you don't need to enter a password or take any other step to confirm your identity

clicking around you should be able to bring up a QR code, which you scan on your phone to register your account with the authenticator. When you open the app, you'll be able to bring up a cryptographically generated six-digit OTP for each registered service.

This may seem similar to receiving an OTP via SMS, but it's considerably more secure. There's no chance of anyone else intercepting the code, as it's generated locally on your phone. And each generated code lasts for only 30 seconds before it's replaced by a new one – so even if someone is spying on your activity, they can't reuse your code because it will have expired.

However, using an authenticator app isn't wholly frictionless. The app may be free, but you still need to register all your services with it – and then every time there's a login challenge you need to dig out your phone and find the relevant code for the website or app you want to access.

Something you have

To get around the awkwardness of authenticator apps, some services have adopted an altogether simpler approach. If you've entered your Google password on a new device in the past few years, you may have received a prompt to confirm the login on your phone or tablet. In this case there's no code to enter: a requester pops up on the mobile device saying "was this you?", and if you click "yes" then Google takes you at your word.

At first glance this may seem rather pointless, but it's actually a huge step up in security from using the password alone, as it also requires something you have: your phone or tablet. Indeed, in order to confirm the prompt, you need to unlock the device using a passcode or biometric authentication, so you're actually protected by 3FA.

Google isn't the only service that uses an unlocked device as evidence of identity. Online payments made with Apple Pay may require Touch ID on an iPhone or iPad; in my case, when I make an online payment using my debit card, I get a prompt to open the Santander banking app on my phone and tap "I requested this" to confirm the transaction. The app itself requires a thumbprint or passcode before it will open, so by the time I see the button I'm already authenticated. It's a convenient way to provide very strong security, and it's notable that it doesn't use passwords – traditionally the most vulnerable identity factors – at all.

Passkeys please

The next generation of 2FA builds further on the idea of device-based authentication. You may already have heard of passkeys – a recent FIDO initiative that aims to make secure logins invisible and instant. Frankly it's a forgettable name, but the execution is hard to fault: when you log into a system that uses passkeys, you don't normally need to enter a password or take any other step to confirm your identity. You don't even need to provide a username. Just do what you'd normally do to unlock your device – such as scanning a fingerprint or smiling briefly at the camera – and the site or application will open for you straight away.

That may sound like very little security, but it goes without saying that there's more going on behind the scenes. The first time you access a site or application that supports the new technology, you'll be prompted to generate a passkey – a cryptographic signature that's tied to your account on the

Reviews

The biggest, best, most exciting products in technology – reviewed and rated

HP Envy Move

Luggable PCs are back, and this slick all-in-one system offers a top-notch 24in screen – even if there are niggles to iron out

SCORE ★★★★☆

PRICE £1,083 (£1,300 inc VAT) from hp.co.uk

Some trivia to kick things off: did you know that Steve Wozniak only joined forces with Steve Jobs to form Apple after Wozniak's pleas to his then employer, Hewlett Packard, to build a personal computer fell on deaf ears? This was in the late 1970s, when HP preferred to defend its lucrative calculator business. By 1980 it had changed its mind, producing its first PC, but this targeted engineers rather than the mass population.

Even in those early days, so-called luggable computers were starting to emerge. Take the ground-breaking

BENCHMARKS

Geekbench 6.2 single-core

2,426

0 — 1,000 — 2,000 — 3,000 — 4,000

Geekbench 6.2 multicore

8,978

0 — 5,000 — 10,000 — 15,000 — 20,000

3DMark Time Spy

1,374

0 — 5,000 — 10,000 — 15,000 — 20,000

BATTERY LIFE (Video rundown)

4hrs 30mins

0 — 5 — 10 — 15 — 20
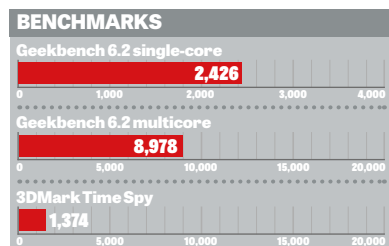
Osborne 1, which launched back in 1981 complete with a 5in CRT display. Admittedly, this weighed 11kg and didn't include a battery, but squint and you can draw a line between the Osborne and the Envy Move. It's just that HP's luggable PC happens to have a 23.8in touchscreen display, 10-core processor and a battery that keeps it going for more than four hours.

■ Return of the luggable

Another big difference is that HP doesn't envision you lugging the Envy Move with you onto trains and planes. Instead, it imagines that you'll grab it by the handle – securely built into the top of the chassis – and transport it between rooms or desks as required. It could even act as a family PC, flitting between study, play room and kitchen.

Although a 4.1kg weight is featherlight when compared to the Osborne 1, the Envy PC definitely isn't something I would want to carry around with me for long. Especially when there's no protection for the

ABOVE The Envy Move's 23.8in display has a sharp resolution of 2,560 x 1,440

"HP imagines that you'll grab it by the handle – securely built into the top of the chassis – and transport it between rooms or desks"

LEFT Plug a cable into the HDMI input and you can use the Envy Move as a second screen

screen; all it would take is one ill-advised bump and terrible things could happen (consider accidental damage cover to supplement the single year of warranty).

It's clear, though, that HP has given plenty of thought to this unit's portability. Two feet keep it supported when at rest, but lift the Envy Move and these spin sideways to align with the base of the unit. That means they don't jut out when you're carrying it. As soon you place the Envy on a surface they spin back outwards.

There's also a kangaroo-style pouch at the rear to hold the combination keyboard/touchpad unit.

■ Real-world use

The downside to HP's design is that you can't tilt the screen back beyond around 5°. Nor is there any height adjustment. As a result, you'll find yourself looking slightly downwards if you use the Envy Move in a sitting position, which isn't as ergonomically sound as a typical desk monitor setup – but is far superior to being crouched over a laptop for hours.

I also found it much easier to work efficiently on the Envy Move than on a laptop. Some of that stems from having a separate keyboard. If I was

using this PC permanently, I would strongly recommend buying a better keyboard than HP's offering, though: there's no tilt here, the key action is basic and it only has a slim design in its favour. While the built-in touchpad will be useful in emergencies, I used it for precisely two minutes before reaching for a Bluetooth mouse.

I have no complaints about the screen. A peak brightness of 314cd/m² is plenty for inside use, while its colour coverage was better than I anticipated: 96% of the sRGB gamut and 70% of DCI-P3. Colour accuracy was terrific, with an average Delta E of 0.54, and importantly for anyone who spends their days in Word or Excel, whites don't suffer from any off-hue tinge.

But what I really like about this screen is its resolution. HP could easily have opted for a 1,920 x 1,080 panel, but instead chose a 2,560 x 1,440 display – that makes a huge difference both for sharpness and when it comes to working on multiple windows. You'll have no problem viewing two windows side by side, and I even found it usable with one big central window and smaller reference windows on either side.

▆ Webcam wonder
HP has given careful thought to the webcam, too. This records videos at 1440p rather than 1080p, and both detail and colour accuracy are well above average. You'll make a fine impression during team calls. My only criticism is of the microphone, as it made me sound like I was calling from the bottom of a well with far too much echo. I tried tweaking settings in the myHP app but to no avail.

At first I was blown away by the dual 5W speakers. Not only are they loud, they can cope with multi-layered Björk tracks and bring welcome bass to any party. But – and trust me, this is a big but – HP, along with Bang & Olufsen, has attempted to use AI to detect where you're sitting and adjust the audio accordingly. It appears to use the webcam to do this, so I strongly recommend you use the privacy switch to override the feature. Otherwise, you'll get weird ups and downs in volume and balance.

Also, oddly, there are occasional splutters from the speakers, like when the needle used to hit dust on an LP. I can only assume this is the "AI tuning" at work and will be ironed out in a future update. If HP can get rid of these annoyances then it has arguably the best set of speakers you'll find on

an all-in-one or monitor. Until that point, they're simply annoying.

▆ Covering the basics
It seems almost mundane to talk about speed, and on paper the Envy Move looks deeply average: a middle-of-the-road Core i5 processor, Intel Iris Xe graphics, 16GB of RAM (embedded onto the motherboard). However, in practice I found this computer whacked through tasks, even when away from mains power.

Consider its Geekbench scores. A 2,426 result in the single-core test puts it in the top tier, while the fact it nudges 9,000 in the multicore test underlines that this machine can cope with demanding tasks on occasion. You may need to wait a while for core-intensive work, however, as a result of 5,102 in Cinebench's R23 multicore test hints that multithreaded applications aren't its strong point. Neither is 3D acceleration. A score of 1,374 in 3DMark Time Spy is low, while I could only persuade the Envy Move to reach 40fps in *Shadow of the Tomb Raider* by dropping to 720p and lowest settings.

HP has chosen a speedy 1TB SSD, with 2,199MB/sec sustained reads and 2,948MB/sec writes in CrystalDiskMark 8. And there's good news for anyone who decides to replace the storage capabilities at some point, because this machine is surprisingly repairable. HP supplies a comprehensive "teardown" video that gives you instructions at **tinyurl.com/353hpenvy**.

▆ Moved to buy?
One of the reasons I looked for this repairability is the battery. It's all very well that it gives you four-and-a-half

RIGHT A pouch at the rear holds the combo keyboard/ touchpad unit

LEFT The 1440p webcam offers fine detail and decent colour accuracy
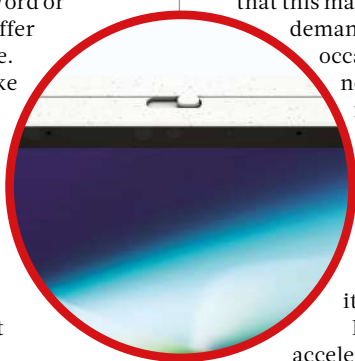
hours of life now, but what about three years down the road? Five years? Replacing the battery is more involved than the SSD, so you may want to ask a repair specialist, but at least it's feasible.

Still, in the very worst scenario, this PC can fall back to being a second screen. Simply plug your cable into the HDMI input, which you'll find on the right-hand side. That's also where the external DC power supply plugs into; it's a slimline 90W affair, but there isn't room for it in the pouch next to the keyboard.

There are two more ports on the left-hand side: one USB-C, one USB-A. That's a meagre haul, but they're both rated at 10Gbits/sec and you can use the USB-C port to connect a second display.

Is the HP Envy Move worth £1,300? Well, three months ago we reviewed the Dell Inspiron 24 All-in-One (*see issue 350, p47*), which cost £749 for a 1080p panel and lesser performance. The Envy Move is superior in every way. And that battery isn't simply a tickbox feature: by making this PC so easy to move from one room to another, by freeing you from power sources, it becomes a mobile computer. You don't even need to think about the transition from one place to another, you just unplug and move it.

So, yes, it's worth £1,300, if it fits in with the way you want to use a computer. But if all you're looking for is a luggable in the original meaning of the word, then save your pennies and buy the Dell instead. **TIM DANTON**

> **"By making this PC so easy to move from one room to another, by freeing you from power sources, it becomes a mobile computer"**

BELOW At 4.1kg you won't be carrying it around too much, but it's not back-breaking

SPECIFICATIONS
10-core (2 P-cores, 8 E-cores) Intel Core i5-1335U processor ● Intel Iris Xe graphics ● 16GB LPDDR5 RAM ● 23.8in 60Hz IPS touch panel, 2,560 x 1,440 resolution ● 1TB M.2 PCI-E Gen4 SSD ● Wi-Fi 6E ● Bluetooth 5.3 ● 5MP IR webcam ● USB-C 3.2 Gen 2 ● USB-A 3.2 Gen 2 ● 83Wh battery ● Windows 11 Home ● 552 x 149 x 37mm (WDH) ● 4.1kg ● 1yr limited hardware warranty ● part code 8U897EA#ABU

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SCAN

Lenovo Yoga AIO 9i (Gen 8)

An excellent all-in-one in so many ways, but at this price you should expect a better webcam and speakers

SCORE ★★★★☆

PRICE RTX 4080, £2,083 (£2,500 inc VAT) from lenovo.com

My first reaction on seeing the Yoga AIO was simple: awe. The metal bar that connects the display to the base makes it look as if the display is floating in mid-air.

The 31.5in, 4K IPS panel is just as eye-catching. I couldn't look away from the trailer for *Spider-Man: Across the Spider-Verse*, with vivid colours matched with detail: I could even see the fake film grain. It backed this up with an excellent performance in our technical tests, reproducing 100% of the DCI-P3 gamut and hitting 503cd/m² brightness.

There's speed galore here, too, with our review model including an Intel Core i9-13900H processor, 16GB of RAM and a 512GB SSD. A multicore score of 13,123 in Geekbench 6.2 hammers home the power of the processor, and it converted a 4K video into 1080p in a swift 4mins 26secs.

Aggravatingly, our unit only included Intel Iris Xe graphics. Fine for US buyers, where that spec (with a 1TB SSD) is listed at $1,880, but Lenovo's UK arm is only shipping one model. This includes Nvidia's mobile RTX 4050 (plus 32GB of RAM and a 1TB SSD), so games will run much more smoothly than on my system.

What bodes well for gamers is that our test unit returned 2,110 in the 3DMark Time Spy test, which is about the best we've seen from Iris Xe graphics. That should boost to over 8,500 with an RTX 4050 chip, and if you tweak the settings you may even get playable results at 4K in modern games such as *Balder's Gate 3* and *Cyberpunk 2077*. However, it will be happier at 2,560 x 1,440, and if you want 60fps or higher then you'll probably need to drop down to 1080p.

With no room for a second SSD (there are two M.2 slots, but the second is for the Wi-Fi 6E card), you may want to attach an external drive to one of the Yoga AIO's two USB-C ports. These are at the back of its base, along with an HDMI 2.1 out, two USB-A 3.2 Gen 2 ports and an audio jack. I found the port placement annoying, as I was forced to pull the PC closer to me on my desk to plug anything in. And it's a hefty 8.2kg.
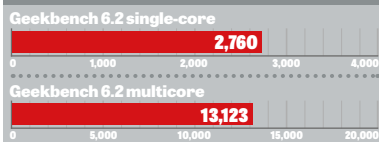
The Yoga ships with a simple wireless keyboard and mouse. While the former comes with a full number pad and sizable keys, its shallowness leaves much to be desired, but then I'm used to mechanical keyboards. The mouse isn't the most comfortable, with flattened top edges and a bulbous rear; it's responsive enough for casual use, but I couldn't wait to get back to my normal unit.

I feel similarly about the speakers. These are tucked into the back, nestled within the circular protrusion stamped with a Yoga logo. The good: they're loud and capable enough to handle music. The bad: in films, I found they struggled to balance hectic action with actors' voices.

The Yoga AIO 9i's microphone is fine for conferencing and not much else.

ABOVE The stunning 31.5in, 4K IPS display almost looks as if it's floating in mid-air

"It's a brilliantly crafted all-in-one. However, when paying £2,500 you have every right to expect top-quality peripherals"

LEFT You'll find the speakers and all the ports at the back of the PC

Audio is clear, without obnoxious background noise, but you won't sound particularly professional. The 5MP webcam built into its upper bezel is impressive on paper but again I wouldn't use it beyond the occasional web call. There's a webcam shutter, but it's on the right-hand side of the base and a hassle to reach.

The webcam is one area where it falls behind its obvious rival, HP's Envy 34 All-in-One (*see issue 335, p46*). The Envy uses Intel's 12th generation Core chips and only includes Nvidia RTX 30 series graphics, but the magnetically attached webcam not only produces far superior results but moves wherever you want. The cheapest Envy – with a Core i7-12700, 16GB of RAM, 1TB SSD and RTX 3050 graphics – costs £1,799 inc VAT.

Where does this leave the Lenovo Yoga AIO 9i? If you want speed and a phenomenal display then you'll be delighted. It's a brilliantly crafted all-in-one, too. However, when paying £2,500 inc VAT for a computer you have every right to expect a top-quality webcam, speakers and peripherals. **MOMO TABARI**

SPECIFICATIONS (as sold in UK)
14-core (6 P-cores, 8 E-cores) Intel Core i9-13900H processor ● 6GB Nvidia GeForce RTX 4050 graphics ● 32GB LPDDR5-5600 RAM ● 31.5in 60Hz IPS non-touch panel, 3,840 x 2,160 resolution ● 1TB M.2 PCI-E Gen4 SSD ● Wi-Fi 6E ● Bluetooth 5.2 ● 5MP IR webcam ● USB-C 4 ● USB-C 3.2 Gen 2 ● HDMI 2.1 output ● 2 x USB-A 3.2 Gen 2 ● 3.5mm jack ● Lenovo Ultraslim wireless keyboard and mouse ● Windows 11 Home ● 724 x 253 x 543mm (WDH) ● 8.2kg ● 1yr C&R warranty

BENCHMARKS

Geekbench 6.2 single-core	
2,760	

0 — 1,000 — 2,000 — 3,000 — 4,000

Geekbench 6.2 multicore	
13,123	

0 — 5,000 — 10,000 — 15,000 — 20,000

How we test

Laptops and PCs

We run a selection of benchmarks on all the PCs and laptops we test. Where possible, we use a cross-platform test so we can compare Windows and macOS machines, which is where both Geekbench and Cinebench R23 come into play. Both push the CPU to its limit, exposing how well cooled a system is.

We run extra tests for Windows systems. We use our own benchmarks to test photo-editing, video-encoding and multitasking speeds. We then switch to PCMark 10 to benchmark systems in office tasks, content creation and basic tasks such as web browsing and video calls. We also run 3DMark Time Spy and a selection of benchmarks in games such as *Metro Exodus* and *Shadow of the Tomb Raider*.

For laptops, we test battery life with Wi-Fi on and the screen brightness set to 150cd/m². We fully charge the laptops and drain them until they reach 5%. For Windows laptops, we will use a mix of PCMark 10's light-use and video-based tests, or a web surfing benchmark where a laptop automatically visits sites until the battery dies. We also use this test for MacBooks.

ABOVE We put PCs and laptops through our intensive set of benchmarks

Screen quality

In each laptop, phone, tablet and monitor review, you'll see our conclusions about the screen quality. Some of this will be subjective, but we also test each screen using a Display i1 colorimeter. We measure maximum brightness, colour accuracy and (for monitors) consistency – there may be a difference in, say, brightness from the middle and the edges of the panel.

We also measure Delta E, which is a guide to how accurately panels display colours. Anything under 1 is excellent and likely to be difficult for the human eye to distinguish; between one and two is still strong; above this suggests a panel that you shouldn't trust for colour-accurate photo editing.

LEFT We use a Display i1 colorimeter to measure sRGB gamut coverage and Delta E

good test of the processor and memory in particular, and include both a test for single-core and multicore performance. See below for a selection of scores to provide a reference of what's good... and what's not so good.

We also run 3DMark Wild Life test to give a measure of gaming performance.

As with laptops, we test phone and tablet battery life by playing a full-screen video until the battery runs out with the device. To simplify the test, we use Airplane mode. We set the brightness to as close to 150cd/m² as we can get in the device's settings.

BELOW We play a video with the screen set to 150cd/m² to test battery life

Phones and tablets

We run a selection of publicly available benchmarks on all the phones and tablets we review. First, we run Geekbench 5 and 6. These are a

GEEKBENCH 5 (MULTICORE)

Apple iPhone 14 Pro Max Apple A16 Bionic	5,333
Apple iPhone 14 Apple A15 Bionic	4,553
Apple iPhone 13 Pro Max Apple A15 Bionic	4,549
Apple iPhone 12 Apple A14 Bionic	3,859
OnePlus 10T Qualcomm Snapdragon 8+ Gen 1	3,476
Google Pixel 6 Google Tensor	2,696

HIGHER IS BETTER
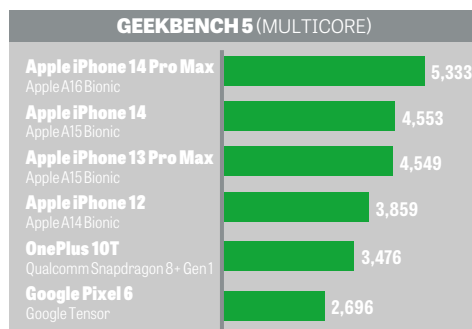
What our awards mean

PC PRO RECOMMENDED

Recommended
This, quite simply, is a product we recommend you buy – if it meets your needs.

PC PRO ★★★★★ A-LIST

A-List
The best buy in its category right now. The product will also feature on our A-List, starting on p14. It's updated each month.

PC PRO LABS WINNER

Labs Winner
Each month we run a group test, or Labs. This product has managed to beat all others to top position.

The pcpro.link

Throughout the magazine you'll see pcpro.link shortcuts. Enter these into the address bar of your browser and it will take you to a particular page, which will either be too long or awkward for us to publish or will take you to the precise shop from which to buy. If it's Amazon, note that we have an affiliate deal in place so we will receive a commission from each sale. This will never affect our verdict of a product, and if another reputable vendor is selling the product cheaper then we will use that instead.

Prices will vary

Prices we publish are correct on the day we publish, but we often see prices change, especially on sites such as Amazon. However, we do work with British PC retailers to ensure the prices we quote for their systems are correct. If the price isn't being honoured, contact us via letters@pcpro.co.uk.

Scan 3XS GWP TR Ada

The GWP TR Ada is the most powerful workstation we've ever tested by a considerable margin

SCORE ★★★★★

PRICE £14,167 (£17,000 inc VAT)
from scan.co.uk (code: LN143291)

PC PRO
RECOMMENDED

Workstation technology is the pinnacle of desktop PC power, and this month we're testing a computer that showcases some of the latest high-performance components. Not only is the Scan 3XS GWP TR Ada our first look at AMD's latest Ryzen Threadripper, back after a hiatus, but also Nvidia's Ada generation graphics, and it boasts a bevy of PCI-E 5 NVMe storage as well.

First, that processor. The AMD Ryzen Threadripper 7980X is top of the resurgent range, offering 64 cores running at a base 3.2GHz but with a boost up to 5.1GHz. Scan has chosen Corsair H150i Elite Capellix RGB liquid cooling to eke the most out of this processor. The 360mm version has been installed on the front of the chassis, with three 120mm fans providing plenty of heat dissipation.

With the Ryzen Threadripper supporting quad-channel memory, Scan naturally populates all four DIMM sockets of the Asus Pro WS TRX50 Sage WiFi motherboard. These are 32GB 4,800MHz Samsung ECC Registered DDR5 modules, for a total of 128GB. You would need to replace all of them if you wanted more memory up to the motherboard's 1TB maximum, but 128GB should be enough for the lifetime of this system.

■ No expense spared

Another top-level component is the Nvidia RTX 6000 Ada graphics, which uses Nvidia's Ada Lovelace architecture, a 4nm design that takes professional GPU performance to the next level and is used in the incredibly potent GeForce RTX 4090 consumer graphics card. The RTX 6000 Ada packs 18,176 CUDA cores, a

considerable upgrade on the 10,752 cores of the A6000 it replaces. Both cards have 48GB of GDDR6 memory, but the Ada's memory is faster (2,500MHz versus 2,000MHz) so bandwidth has increased from 768GB/sec to 960GB/sec. The GPU clock is also up to 2,505MHz on boost, compared to 1,800MHz, so this is a seriously fast 3D graphics accelerator. Scan has spared no expense when it comes to storage, either. The boot drive is a single 2TB Corsair MP700 NVMe M.2 device. This takes advantage of the AMD Ryzen Threadripper 7000 series' support for PCI-E 5. Running CrystalDiskMark 8, it delivered 11,492MB/sec reading and 11,773MB/sec writing, which are phenomenal levels of throughput. As if this wasn't enough, there's an 8TB array consisting of four more of the same drive in a RAID0 configuration, installed in a

RIGHT There are 10GbE and 2.5GbE LAN ports on the back, plus Wi-Fi 7 within

ABOVE It may look like a radiator, but the power inside the GWP TR Ada is phenomenal

"We were expecting top performance from the new Threadripper, but we weren't quite ready for just how fast this system is"

LEFT The drives offer throughputs of incredible speeds

Hyper M.2 X16 expansion card that sits in one of the motherboard's x16 PCI-E 5 slots. This array delivered mind-blowing 34,186MB/sec reading and 42,176MB/sec writing. That's not a misprint – you're getting 30 to 40GB/sec throughput. This will make editing even 8K video relatively painless, for example.

■ Touch of style

This plethora of potent components has been housed in a sizeable Fractal Design North chassis. The slats down the front make this look more like a stylish freestanding radiator than a PC, and it's packed with features. There are two mounts for 2.5in drives, and two more for 3.5in or 2.5in units. None are used as all of Scan's storage is NVMe-based. The power supply is a 1,000W Corsair RM1000X 80 Plus Gold unit, which should be well within its comfort zone despite the power-hungry core components. Even under full load, this isn't a noisy computer.

The Asus motherboard offers both 10GbE and 2.5GbE LAN on the backplane, plus a built-in Wi-Fi 7 2x2 radio that can operate at up to 2.8Gbits/sec. There are three PCI-E 5 slots, but the two x16 ones are taken by the graphics and RAID storage array adapter, while the third operates in x8 mode. There's also an x16 PCI-E 4 slot with a second that operates in x4 mode. The board contains three M.2 storage slots, with two operating at PCI-E 5 x4 speed (one taken by the boot drive), plus a third with PCI-E 4 x4 performance. The motherboard also has hardware and software support for Asus IPMI remote management expansion cards. However, there are only two 20Gbits/sec USB-C ports – one on the backplane and one on the top of the chassis at the front. The rest are Type-A ports of lesser speeds.

■ Blasted with speed

We were expecting top performance from the new Threadripper, but we weren't quite ready for just how fast this system is. An overall score
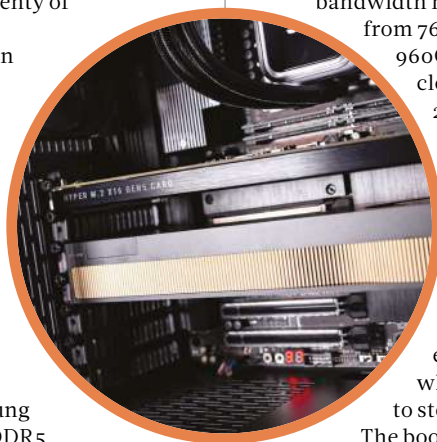
ABOVE Power trip: the 1,000W Corsair PSU is an 80 Plus Gold-certified unit

in the *PC Pro* benchmarks of 954 is way ahead of anything we've tested before. Most of this is provided by the incredible 1,224 in the multitasking test, which is no surprise with 64 cores available. But the video result of 892 is phenomenal as well. Only the image editing score of 267 has been beaten before. This is a mostly single-threaded test, and there are CPUs with faster boost core frequencies.

If you want a true demonstration of how incredible this system is, however, look no further than the Maxon Cinebench R23 multithreaded result of 107,189. Putting this in perspective, the fastest 64-core Threadripper Pro 5995WX workstation we've tested – the Armari Magnetar MC64TP (*see issue 348, p88*) – only managed 76,330. The single-threaded result of 1,728 shows the improvement, too, as the Magnetar managed 1,492, although CPUs with lower cores and higher frequencies such as the Ryzen 7000 series or recent Intel Core chips do better in this test.

Further underlining these abilities, the Blender Gooseberry render took only 94.6 seconds using the CPU, the first time we've seen a processor complete this frame processing task in less than two minutes. On GPU (using CUDA) it took 69.2 seconds, much less time than any other professional card we've tested. The LuxMark 3.1 score of 26,426 is similarly high, showing just how much GPU compute power the Nvidia RTX 6000 Ada has on offer.

■ Tour de force

This GPU power translates into incredible 3D modelling capabilities. The standout result in SPECviewperf 2020 is an astonishing 1,235 with the snx-04 viewport, almost twice the fastest scores we've seen before. The catia-06 result of 208 is also impressive, as is

AMD Ryzen Threadripper is back – and it means business

There are plenty of good reasons to welcome back the non-Pro Threadripper, which is better than ever

For a few years, it seemed like the regular AMD Ryzen Threadripper was history. After the Pro version arrived, there was no non-Pro 5000 series. But now the vanilla Threadripper is back with the 7000 generation. It's based on the same Zen 4 core as the Ryzen and Ryzen Threadripper Pro 7000 series CPUs, manufactured using variants of TSMC's 5nm fabrication process, but sits between the two in features and price.

Where the Ryzen 7000 series tops out at 16 cores, the Ryzen Threadripper 7000 series offers 24-, 32- and 64-core iterations. The Pro goes from 12 to 96 cores. Further differentiation comes with memory configuration. All three 7000 series ranges support DDR5 memory at up to 5,200MHz, but where the basic Ryzen has a dual-channel controller, the Threadripper's controller is quad-channel and the Pro's is eight-channel.

All three ranges now offer PCI Express 5, but the number of lanes available is another point of difference. The basic Ryzen has 28 PCI-E 5 lanes, but the Threadripper has 48, plus 24 PCI-E 4 lanes, and the Pro has 128 PCI-E 5 lanes. The greater number of lanes will mean that faster storage devices such as NVMe M.2 drives can be attached, faster networking devices can be used, and more graphics cards can be installed.

Since we last had non-Pro Threadrippers, AMD's Zen core technology has moved on apace. Both the previous 3000 series and new 7000 series top out

at 64 cores, but the 3000 version (3990X) had a base clock of 2.9GHz with 4.3GHz boost, whereas the 7980X as found in this month's Scan system has a base clock of 3.2GHz with 5.1GHz boost. This will offer significantly better performance with software that favours fewer, faster cores *and* with applications that can use as many cores as possible. With AMD's Precision Boost 2, you'll get as many cores as your cooling and motherboard power delivery can handle to run at maximum frequency, although some will be flagged as the most capable after manufacturer testing. Putting this further in perspective, the 32-core AMD Threadripper 2990WX only had a base clock of 3GHz and a boost of 4.2GHz, so the 7980X is a huge leap forward.

As such, this Zen 4 -based Threadripper represents another significant update for AMD. Intel has been posing a challenge to the Ryzen 7000 series with its 13th generation Raptor Lake chips, but its Sapphire Rapids Xeon workstation processors have only arrived recently and max out at 56 cores and a 4.8GHz boost frequency. The Threadripper undercuts it in price while the Threadripper Pro now goes up to 96 cores.

With the return of the non-Pro Ryzen Threadripper, there's a more affordable route once again if you want more than 16 cores in your workstation for the best possible multithreaded performance.

604 in solidworks-07, showing that CAD and product design capabilities are unparalleled, although the creo-03 score of 76 is surprisingly mediocre. For 3D animation, 295 in

BELOW The powerful components are kept cool by Corsair's H150i Elite Capellix RGB liquid cooling

3dsmax-07 and 807 in maya-06 tell their own story.

The Scan 3XS GWP TR Ada is a tour de force. Its 64-core AMD Ryzen Threadripper blows everything that went before out of the water with multithreaded tasks, and it's no slouch with single threads, either. The Nvidia RTX 6000 Ada graphics also dominate for viewport acceleration or GPU rendering, and storage throughput is unparalleled. Of course, this workstation is expensive, but you certainly get what you pay for: the best possible workstation performance on the market. **JAMES MORRIS**

SPECIFICATIONS

3.2GHz AMD Ryzen Threadripper 7980X CPU ● Asus Pro WS TRX50 Sage WiFi motherboard ● 128GB 4,800MHz ECC Registered DDR5 SDRAM ● PNY Nvidia Quadro 6000 Ada graphics with 48GB GDDR6 ECC memory ● 2TB Corsair MP700 M.2 NVMe PCI-E Gen5 SSD ● 4 x 2TB Corsair MP700 M.2 NVMe PCI-E 5 SSD RAID0 array ● Fractal Design North chassis ● Windows 11 Pro 64-bit ● 3yr parts & labour warranty (1yr on-site, 2yrs RTB)

Minisforum UM780 XTX

A formidable AMD Ryzen 7 chip powers this mini PC, making it a versatile choice for gaming or work

SCORE ★★★★☆

PRICE 32GB/1TB, £541 (£649 inc VAT) from store.minisforum.uk

PC PRO RECOMMENDED

This mini PC packs a powerful punch thanks to an AMD Ryzen 7 7840HS. Having such power in a compact PC isn't a surprise, with the Geekom Mini IT 13 (*see issue 350, p46*) showing a similar turn of pace thanks to its Core i9-13900H, but there's one extra that marks the Minisforum UM780 XTX out from the crowd: you can upgrade from integrated graphics to an external GPU using its OCuLink interface.

Using OCuLink fills one of the two available M.2 slots, but in return you get even more bandwidth than USB 4 or Thunderbolt 4. As such, eGPUs (while likely costing more than this mini PC itself once you factor in the cost of the graphics card) become a realistic option.

This capability means Minisforum can name gamers and creatives as its target market, but don't discount the AMD chip's built-in Radeon 780M graphics. A 3,130 return in 3DMark Time Spy is a big jump over the 1,922 scored by the Geekom unit, and if you keep settings at low or medium then *Borderlands 3*, *F1 23* and *Shadow of the Tomb Raider* will all run smoothly (50fps or above) at 1080p.

The Ryzen 7 7840HS is even more potent in everyday tasks. Using eight of AMD's latest Zen 4 cores, with a maximum clock speed of 5.1GHz, it thundered through our tests. Its single-core return of 2,460 was a fraction higher than the Core i9 in the Geekom PC, while a 12,130 score in the multicore test is almost 700 points
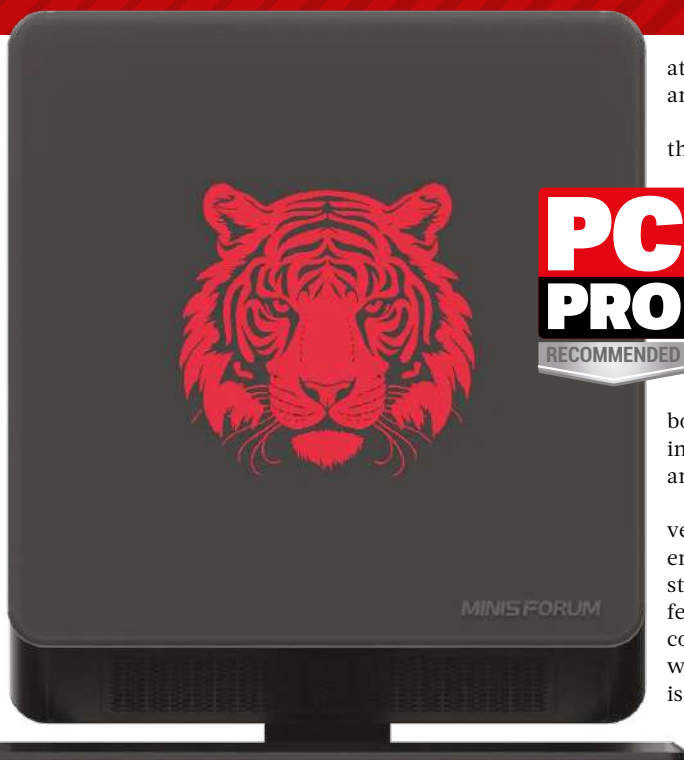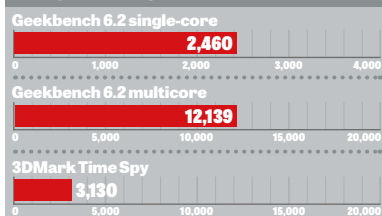
faster. Not bad when you're comparing a Ryzen 7 to a Core i9.

This impressive performance extends to video editing as well. Working with RAW Lite footage from a Canon EOS R5 C, the UM780 XTX managed the data-intensive task with ease. And anyone hoping to dabble with local AI processing will appreciate the inclusion of Ryzen AI.

There is fan noise, but it's kept to a minimum thanks to a clever cooling system. This isn't merely about the fans – which adjust intelligently depending upon demand – but the metal casing of the mini PC itself, which acts as a giant heatsink. Minisforum has also made the PC look attractive, with a choice of three colours: Champagne, Vivid Cerulean and Obsidian Black.

Unusually, there's also some bling. You don't have much control over this – the backlight merely alternates through colours – but you can fit the supplied tiger etching or even create your own. The etching slips into a magnetic top cover.

There are good mounting options, too, with a choice of vertical and wall mounting so this PC can fit neatly into any workspace or desktop. There's a VESA mount, too, or simply use the supplied stand. You can quickly access the inner workings – despite a cable that's fiddly to remove and

ABOVE The Ryzen 7 7840HS puts a tiger in your tank – or your mini PC, at least

> "From everyday office tasks to gaming and creative work, it offers a level of versatility and power that's rare in compact PCs"

LEFT Access to the PC's innards is simple

BELOW There are USB ports aplenty on the front and the back

attach – to access the RAM socket and M.2 slots.

There's no shortage of ports on the outside. One USB-C 4 and two USB-A 3.2 Gen 4 ports sit on the front, alongside the audio out and reset button. The same trio of USB ports are on the back, alongside video outs for HDMI and DisplayPort, plus the OCuLink port (an M.2 adapter is included in the box but not pre-fitted), power input for the 120W power brick and twin RJ-45 connectors.

The dual 2.5GbE ports provide versatile connectivity options, enabling fast data transfers and a stable network connection. This feature is particularly useful for collaborative work environments where quick, reliable file sharing is essential. It also benefits gamers seeking high-speed, lag-free online gaming.

The downside to the design is that this isn't the most compact mini PC we've tested. The Geekom Mini IT 13 measures 117 x 112 x 49mm, compared to 130 x 125 x 62mm for the UM780 XTX.

The price, however, is competitive. The £649 inc VAT we quote here includes 32GB of DDR5 memory, a 1TB SSD and Windows 11 Home. Those who prefer barebones units can buy the UM780 XTX for £489, but that doesn't include a Windows licence.

The Minisforum UM780 XTX stands out as a high-performance mini PC suitable for a wide range of applications. From everyday office tasks to graphic-intensive gaming and professional creative work, it offers a level of versatility and power that's rare in compact PCs. Not only that, but you can customise the look and style of this mini PC with the addition of the magnetic top plate.

Whether it's seamless multitasking, handling large RAW image files, editing high-resolution video or enjoying gaming (especially if you invest in an OCuLink external GPU), the UM780 XTX consistently delivers top-notch performance. **ALISTAIR JENNINGS**

SPECIFICATIONS
8-core/16-thread AMD Ryzen 7 7840HS processor ● 32GB DDR5-5600 RAM ● AMD Radeon 780M graphics ● Wi-Fi 6E ● Bluetooth 5.3 ● 2 x 2.5GbE ports ● OCuLink port ● 1TB M.2 PCI-E Gen4 SSD ● 2 x USB-C 4 ● 4 x USB-A 3.2 Gen 2 ● HDMI 2.1 ● DisplayPort 1.4 ● 3.5mm jack ● Windows 11 Home ● 130 x 125 x 62mm (WDH) ● 1yr RTB warranty

BENCHMARKS

Geekbench 6.2 single-core

2,460

| 0 | 1,000 | 2,000 | 3,000 | 4,000 |

Geekbench 6.2 multicore

12,139

| 0 | 5,000 | 10,000 | 15,000 | 20,000 |

3DMark Time Spy

3,130
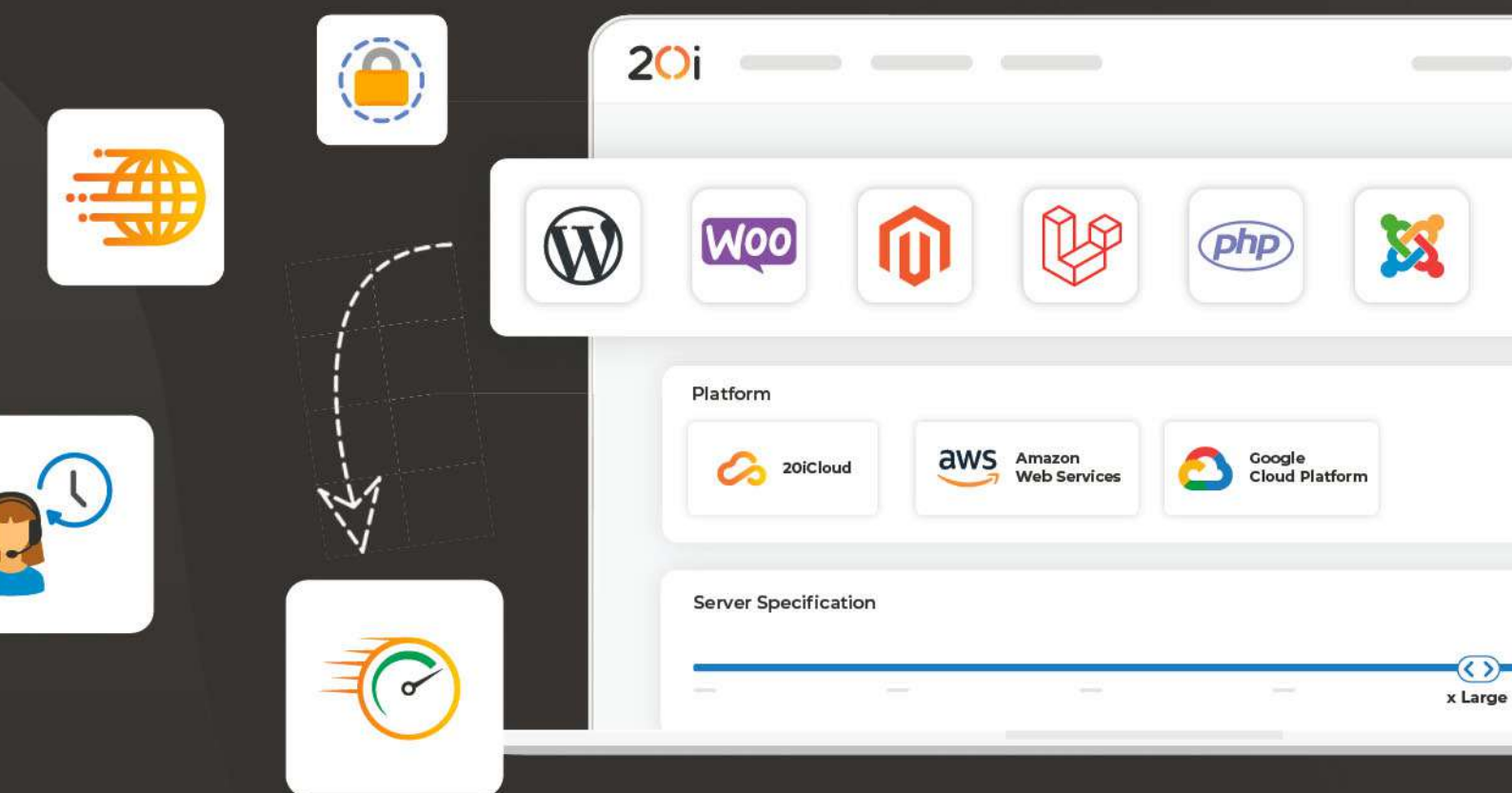
| 0 | 5,000 | 10,000 | 15,000 | 20,000 |

Acer Predator Helios 3D 15 SpatialLabs Edition

A fast and intriguing laptop that uniquely allows you to play games on a 3D screen, but it involves sacrifices

Readers with perfect memories may remember my reviews of the Acer SpatialLabs View and View Pro monitors last year (*see issue 344, p58*). If so, you may recall how impressed I was by this pair of 15.6in portable monitors, which allowed you to view CAD-designed objects and games in 3D without any glasses. With the help of eye-tracking cameras, a lenticular lens and extremely clever software, it didn't simply work – it worked brilliantly.

The downside to this arrangement was twofold. One, the price, with even the cheaper View monitor costing £1,199. The second was the form factor: really, this technology either needs to be built into a big desktop monitor (Lenovo has already announced that it plans to sell one next year) or directly into a laptop.

Acer did release Predator Helios 3D laptops in 2023, but with 12th generation Core chips and 30 series Nvidia processors they were behind the cutting edge. I was much keener to get my hands on this update with the latest silicon inside.

3D gaming fun

Before I start extolling this laptop's 3D virtues (and there are many), some expectation management: not all of your games will work in 3D. The list of supported games is on the SpatialLabs website (**tinyurl.com/353game**) if you want to check before you buy. Once you own the laptop, install Steam and other game launchers of your choice, then fire up the TrueGame app. This filters any games you own that run in 3D and lets you launch them.

The compatible list runs to over 100 games, which sounds fine until you're looking for one that you actually own. In my case, with 72 titles to call upon in Steam alone, that meant *Metro: Last Light Redux* and *Shadow of The Tomb Raider*. Fortunately, Acer supplied my test system with a bunch of supported titles, including *God of War*, *Marvel's Guardians of the Galaxy*, *No Man's Sky* and *The Elder Scrolls V: Fallen Order.*

I was keen to try a racing game, but *Forza Horizon V* – which is on the TrueGame list – failed to load, so I resorted to *No Man's Sky* and *Star Wars Jedi: Fallen Order* instead. And, just like before on the SpatialLabs View monitors, I was soon muttering "absolutely incredible" to myself, such is the quality of the 3D effect. It's like staring into a magical 3D world, to the point that sometimes you forget

ABOVE The Predator Helios 3D has its faults, but is a master of 3D simulation

LEFT The chunky chassis prioritises fan vents over ports

> **"In all the games I tried, the Predator Helios 3D had no problems producing slick frame rates despite all the work it was doing"**

you're playing a game. I often found myself admiring the scenery instead.

How long can you play without your eyes getting tired? In my experience, it's identical to how long you can keep going when playing games generally. Your eyes don't need to do any extra work; they're processing what's being beamed to each eye via the lens. The only time the effect weakens is when you shift suddenly in your seat, or try to look at too oblique an angle (yes, on one occasion I tried to look around an object, a la *Blade Runner*; it didn't work).

Performance

You can only play games in 3D at 1,920 x 1,080 due to the way the technology works. In effect, the 4K (3,840 x 2,160) screen is split in half when in 3D mode, with half the pixels sent to the left eye and half to the right. In all the games I tried, the Predator Helios 3D had no problems producing slick frame rates despite all the work it was doing, and that's a reflection of the power inside: Intel's Core i9-13900H processor, 32GB of DDR5 RAM and 12GB GeForce RTX 4080 graphics make for a potent combination.

This is a meaty chassis, too, and while that has inevitable drawbacks for portability – a 3.3kg weight and a best-case battery life of around four hours do not an ultraportable make – it does leave lots of room inside for cooling. And that cooling works. In

3DMARK TIME SPY

	HIGHER IS BETTER
Lenovo Legion 9i Core i9-13980HX, 32GB, RTX 4090	20,806
Acer Predator Helios 3D Core i9-13900H, 32GB, RTX 4080	18,375
Asus ROG Strix Scar 17 Ryzen 9 7945HX, 32GB, RTX 4090	18,343
Asus ROG Strix Scar 16 Core i9-13900HX, 32GB, RTX 4080	17,823
HP Omen 16 Ryzen 9 7940HS, 16GB, RTX 4070	11,141
Alienware m16 R1 Core i7-13700HX, 16GB, RTX 4060	11,037

SHADOW OF THE TOMB RAIDER (1080p, Highest, no DLSS, fps)

	HIGHER IS BETTER
Lenovo Legion 9i Core i9-13980HX, 32GB, RTX 4090	192
Asus ROG Strix Scar 17 Ryzen 9 7945HX, 32GB, RTX 4090	176
Acer Predator Helios 3D Core i9-13900H, 32GB, RTX 4080	167
Asus ROG Strix Scar 16 Core i9-13900HX, 32GB, RTX 4080	162
Alienware m16 R1 Core i7-13700HX, 16GB, RTX 4060	107
HP Omen 16 Ryzen 9 7940HS, 16GB, RTX 4070	107

BORDERLANDS (1080p, Badass, fps)

	HIGHER IS BETTER
Lenovo Legion 9i Core i9-13980HX, 32GB, RTX 4090	175
Asus ROG Strix Scar 17 Ryzen 9 7945HX, 32GB, RTX 4090	164
Acer Predator Helios 3D Core i9-13900H, 32GB, RTX 4080	145
Asus ROG Strix Scar 16 Core i9-13900HX, 32GB, RTX 4080	143
HP Omen 16 Ryzen 9 7940HS, 16GB, RTX 4070	92
Alienware m16 R1 Core i7-13700HX, 16GB, RTX 4060	84

METRO EXODUS ENHANCED (1080p, Extreme, fps)

	HIGHER IS BETTER
Lenovo Legion 9i Core i9-13980HX, 32GB, RTX 4090	89
Acer Predator Helios 3D Core i9-13900H, 32GB, RTX 4080	80
Asus ROG Strix Scar 17 Ryzen 9 7945HX, 32GB, RTX 4090	74
Asus ROG Strix Scar 16 Core i9-13900HX, 32GB, RTX 4080	72
HP Omen 16 Ryzen 9 7940HS, 16GB, RTX 4070	46
Alienware m16 R1 Core i7-13700HX, 16GB, RTX 4060	41

certain games, the Predator Helios scored higher frame rates than rivals with an RTX 4090 inside – including the ROG Strix Scar series, and those are gaming powerhouses.

Mind you, I put the Predator into Turbo mode to reach such highs, and that means an uncomfortable amount of fan noise. I could still make out the games' audio above the din – just – but if I was playing to win then I'd slap on a pair of headphones. Step down to Performance mode, when the fans vary more depending upon usage, and you'll see a drop off in frame rates by between 5% and 10%.

I used this more office-friendly Performance mode for the rest of the speed tests, and you won't be shocked to hear that it produced great scores. Sticking to multicore results, Geekbench 6.2 returned 16,969, Cinebench R23 26,515 and a superb 10,096 in PCMark 10's Digital Creation test. For those occasions when you're less bothered by speed, Acer's PredatorSense software offers a Quiet mode that lives up to the name.

Load up Nvidia's Studio drivers and this would be a superb tool for 3D creative pros, too. And you can even view the results of your work in SpatialLabs Model Viewer, which supports file formats from "all major 3D modelling software" according to Acer, which goes on to list Blender, Autodesk 3DS Max and Fusion 360 as supported apps. This means you can view 3D models and twist them, zoom in and out, and generally get a feel for what the object looks like in reality.

■ Covering the basics

The only potential downside for creatives is that this is so obviously a gaming laptop in terms of styling. You can turn off the per-key RGB backlighting – lighting that even extends to the rear exhaust ports – but even so it's not a visual wonder. It doesn't help that Acer opts for a plain black finish on the chassis, while the thick bezel at the top of the screen (this holds the cameras) and the bottom makes it look almost old-fashioned.

There's another side effect, which is to make the 15.6in screen look smaller than it is. Nor will gamers love the fact that it's stuck at 60Hz. If you look for it, you'll also spot the tiniest amount of grain against a white background, but this becomes less visible once you pump up the brightness – it goes all the way to 406cd/m² – and all but invisible when you move to colourful backdrops. And colour reproduction is a strength, with 87% of the DCI-P3 gamut on view, an excellent contrast ratio of 1,603:1 and an average Delta E of 0.57.

Acer caters to gamers with a sharp, responsive keyboard, even if it isn't a mechanical affair. Travel is snappy rather than deep, but with the advantage of being relatively quiet. The only obvious compromise in terms of layout is a single-height Enter key, despite the presence of a number pad to the right; your fingers will need to be dextrous if you use this, as its keys are narrower than usual. As is the smooth, glass-coated trackpad, so gamers will as per usual be reaching for their mouse.
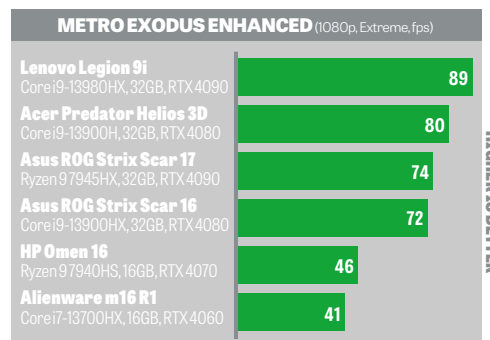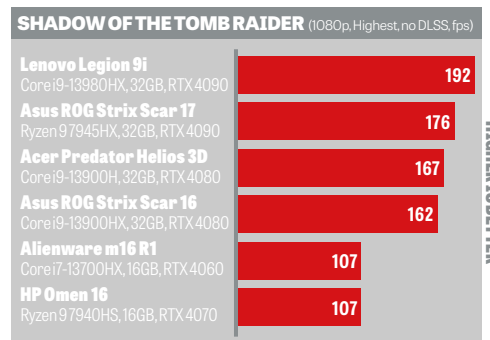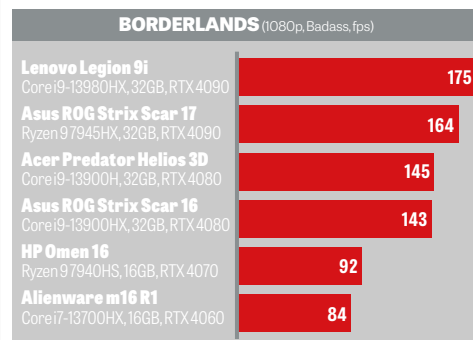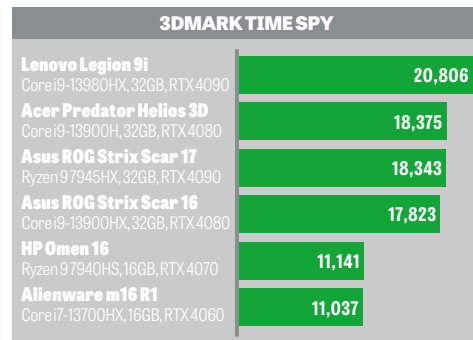
In the battle of seniority, there's no doubt that Acer decided fan vents rule over ports. Set the Predator Helios up on a desk and your Ethernet cable will go into the left despite the power port and HDMI 2.1 output being sensibly placed at the rear. You'll find two USB-C 3.2 Gen 2 ports there too (no Thunderbolt), while the three USB-A ports are relegated to the side of the chassis, along with a microSD card slot and 3.5mm jack.

■ Snap it up?

I hate to end on a negative, but if Acer is accepting requests for the next iteration of this laptop I have a few. First, better speakers, please. Mids and trebles drown out what little bass there is, which I find surprising on such a chunky machine. Then there's the webcam. With such a huge bezel, it's almost criminal that Acer doesn't treat people to something better than this dreary, smudgy offering.

While I'm wishing, a brushed metal finish rather than sturdy but dull

BELOW The plain finish may look dull, but the excitement lies within

black plastic would lift this laptop's visual appeal. Finally, crosshead screws rather than Torx please, and make it easier to repair. In the end, I gave up on my attempt to remove the bottom of this machine as I didn't want to damage it.

Such mis-steps are particularly annoying when there's so much to like here. The keyboard is great despite its non-mechanical nature, and Acer deserves enormous credit for squeezing so much from its components – the 3D effect in supported games is nothing short of spectacular. Ultimately, however, your buying decision comes down to one question. Do you want to play games in 3D? If so, buy the Acer Predator Helios 3D. If not, I would point you to sleeker machines such as the Lenovo Legion 9i overleaf. **TIM DANTON**

SPECIFICATIONS

14-core (6 P-core, 8 E-core) Intel Core i9-13900H processor ● 12GB Nvidia GeForce RTX 4080 graphics ● 32GB DDR5-5600 RAM ● 15.6in non-touch 3D IPS display, 60Hz, 3,840 x 2,160 resolution ● 1TB M.2 PCI-E Gen 4 SSD ● Wi-Fi 6E ● Bluetooth 5.1 ● 2 x USB-C 3.2 Gen 2 ● 2 x USB-A 3.2 Gen 2 ● USB-A 3.2 Gen 1 ● HDMI 2.1 ● gigabit Ethernet ● 3.5mm combo jack ● microSD card slot ● 90Wh battery ● Windows 11 Home ● 359 x 281 x 26.9mm (WDH) ● 3kg ● 1yr RTB warranty ● part code: NH.QLWEK.005

BELOW There's room for three USB-A ports on the sides, and two USB-C at the back

Lenovo Legion 9i Gen 8 (16in Intel)

Pricey, but it delivers for speed, luxury and bragging rights, with both a mini-LED screen and liquid cooling

SCORE ★★★★☆

PRICE RTX 4090, £3,483 (£4,180 inc VAT) from lenovo.com

The Lenovo Legion 9i Gen 8 pulls out all the stops. Its high-end specification would make it a powerful workstation, but as the showy design and a premium GPU indicate, it's aimed at gamers willing to pay top dollar for a unique set of features.

When we say top dollar, we mean it. Our review model, with an Intel Core i9-13980HX processor, 32GB of RAM and 16GB Nvidia RTX 4090 graphics, comes to more than £4,000 including VAT. Lenovo also offers a variant with a 12GB RTX 4080 GPU – UK pricing on that model isn't yet confirmed, but it will still be well over £3,000.

That money buys you both a great laptop but also bragging rights: this is the first laptop with self-contained liquid cooling (*see opposite*). Even the lid is special, made from what Lenovo calls "forged carbon", which bears an organic pattern unique to your laptop. The rest of the chassis is 90% recycled magnesium, which is also lightweight and strong, although admittedly it's a stretch to call the 2.6kg Legion 9i "light". The assembly feels solid with no flex, and a pleasant soft coating adds a luxury feel.

For a 16in laptop the Legion 9i is also relatively compact, with a footprint of 358 x 278mm, but it's hardly low-key. LED light bars span every edge, with 19 programmable zones that can be set to your choice of colours or patterns. Connections at the rear include Ethernet, one USB-A, two Thunderbolt 4, an HDMI output and the power connector. Illuminated port labels help in darker conditions, while a 3.5mm combo audio jack and an SD card slot are on the left edge.

■ Tasteful design

One thing that might divide opinion is the keyboard arrangement: the keys are set uncommonly far forward, allowing for a large vented area above to cool the internals. This means you don't get much in the way of a wristrest area, and the touchpad is more shallow than you'd expect on a 16in laptop. In use, though, I found it perfectly comfortable: the pad has a satisfying clicking action and I experienced no tracking difficulties.

The keyboard itself is rock-solid, with ample key travel and great tactile feedback. It's also terrifically customisable: Lenovo includes eight switchable keycaps in different colours, which you can swap in for any standard key, and the Lenovo Vantage app offers per-key backlighting control, so you can give each key its own glow, and even assign effects such as rainbow, colour wave and rain. Extra switches are also included in the box.

While the design isn't entirely user-upgradable, unscrewing the back and popping it off gives you access to the twin M.2 SSD slots and the battery. The RAM sockets are on the other side of the motherboard, however, so you'll need to perform a major disassembly to reach them. If you think the standard 32GB of RAM might not be enough, consider investing in the optional 64GB upgrade at the time of purchase.

■ Turn up the lights

The Lenovo Legion 9i Gen 8 has a mini-LED display, which is far brighter than OLED or traditional IPS screens. Lenovo claims an astounding peak brightness of 1,200cd/m², and while that's only achievable in HDR scenarios, we measured a still-fantastic average of 667cd/m², with 114% coverage of the DCI-P3 colour space. Even looking at the desktop or browsing the web is enough to make you stop and stare, because everything is so bright and vibrant. It's fantastic for cinematic gaming, or indeed actual cinema, with a native resolution of 3,200 x 2,000 ensuring that everything is sharp.

The sound isn't quite as stunning as the picture, but the stereo speakers under the Legion 9i's palm rests are well above average for a laptop. The audio can be tweaked with the included Nahimic app, which offers a range of equaliser settings and presets; it won't be loud enough to fill a crowded room, but music sounds rich and enjoyable, and there's enough volume for personal or small group listening.

■ Liquid power

The Legion 9i Gen 8 isn't the first laptop we've seen with a Core HX-class CPU and RTX 4090 graphics, but previous contenders have always put these heavyweight components into a larger chassis – one example being the immense 18in Asus ROG

> **ABOVE**
> The stylish Legion 9i is surprisingly portable for such a powerhouse

> "The Lenovo Legion 9i Gen 8 has a mini-LED display, which goes far brighter than OLED or traditional IPS screens"

> **LEFT** The striking lid is made from forged carbon, which is lighter and stronger than aluminium

BENCHMARKS

Geekbench 6.2 single-core
2,878 | 0 | 1,000 | 2,000 | 3,000 | 4,000

Geekbench 6.2 multicore
17,545 | 0 | 5,000 | 10,000 | 15,000 | 20,000

3DMark Time Spy Extreme
10,571 | 0 | 5,000 | 10,000 | 15,000 | 20,000

BATTERY LIFE
■ Web surfing ■ Gaming

4hrs 23mins
59mins
0 | 5 | 10 | 15 | 20
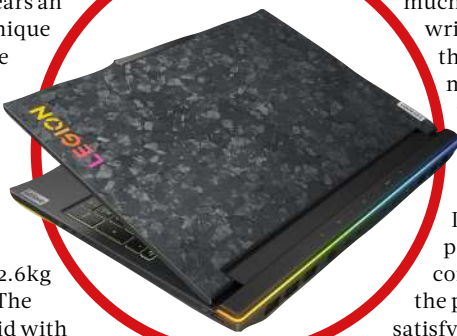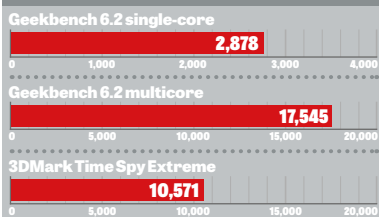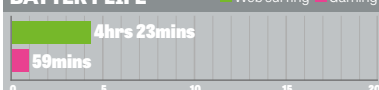
Strix Scar 18 (*see issue 344, p54*).

Despite its smaller size, the Legion 9i holds its own. In Geekbench 6 (not 6.2, as we don't have comparable results for the older ROG Strix Scar), it scored 2,073 in the single-core test and 20,255 in the multicore section, edging ahead of the Scar 18 with scores of 2,066 and 19,323.

The Legion also boasts turbo-charged storage, in the form of two 1TB NVMe SSDs in a RAID0 configuration. This enabled it to complete our 25GB file transfer test at an average rate of 2,501MB/sec – beating the Scar 18's 1,878MB/sec.

For the target market, of course, gaming performance will be of more interest than synthetic benchmarks. Happily, the Legion 9i delivers here, too: I got between 70 and 85 frames per second playing *Cyberpunk 2077* at native resolution with the ray tracing Low preset; switching to DLSS boosted performance to between 105fps and 120fps. Things were even better in *Shadow of the Tomb Raider* at the highest detail setting; here I measured 92fps at native resolution and 192fps at 1080p. Even in the very challenging *Red Dead Redemption 2* at Medium detail, the Legion managed 49fps at native resolution and 108fps at 1080p.

I also tried running the *Metro Exodus* benchmark with RTX settings 15 times in a row, to check how performance holds up over half an hour of gaming, and was delighted to see very little throttling. The Legion kept up an average of 107fps, fluctuating by no more than 10fps between runs. Lenovo says that its liquid-cooling system will kick in to help prevent throttling, but as mentioned in the box this wasn't necessary. Disappointingly.

One thing worth noting is that all this power requires plenty of, well, power. Lenovo supplies a 140W USB power adapter for travel use, but there's also a much larger 330W adapter that's required if you want to run the Legion 9i at its maximum performance.

■ Hot runnings

Gaming laptops tend to have short battery lives, and the Legion 9i is no exception. We got just under an hour of gaming away from the mains, or 4hrs 23mins of web surfing and video streaming – which is on par with comparable laptops.

Even during long, tough tests, though, the Legion was never hot to the touch: during the *Metro Exodus* stress test the external temperature of the Legion 9i's keyboard and touchpad stayed under 38°C, with a maximum of 46°C on the bottom.

That's partly thanks to the sheer amount of air that's continually pumped out of the rear and side vents. While the cooling system does an impressive job, the noise of the moving air is obvious while gaming; it eclipsed softer sounds when I was using the laptop's built-in speakers.

■ Something extra

The Legion 9i comes with a lot of preinstalled software, most of which is pretty good. I've already mentioned the Lenovo Vantage tool, which lets you customise the keyboard backlighting and external LED lighting, and also provides settings such as GPU overclocking.

Advanced system settings are on hand, too, such as always-on USB and rapid charging, and a battery saver feature that prevents the battery from charging above 80% to extend its lifespan. You can also assign custom macros to the number pad keys.

Then there's the Killer Intelligence Centre app, which lets you prioritise game traffic over other apps running on the laptop. A neat touch is that you can optionally route game traffic over Ethernet while sending all other traffic over wireless.

Nahimic's audio app, meanwhile, offers not only audio controls but clever features such as sound sharing, which lets you connect two pairs of headphones at once, and Easy Surround, which turns a Bluetooth speaker into a rear surround.

■ Are you Legion?

The Lenovo Legion 9i Gen 8 is one heck of a laptop. It's also a very expensive one – but if you want this level of performance, your only alternatives are much bulkier systems.

That's not to say there's anything wrong with the Asus ROG Strix Scar 18; some might consider a larger screen a plus point. The Legion, however, has

The liquid-cooled laptop

This Legion is the only production laptop with integrated liquid cooling. Dubbed Legion Coldfront and co-engineered with Cooler Master, it means that Lenovo can pump up to 175W of power into the GPU. That's 25W more than standard. The cooling system runs over the GPU and the VRAM, but it only turns on when the GPU hits 84°C. The rest of the time, the Legion 9i relies on a triple-fan air-cooling system with (Lenovo tells us) 6,333 individual intake vents.

How does this work in practice? If anything, it appears the regular air-cooling system is too effective. An indicator light on the back panel illuminates when liquid cooling is on, but I didn't witness this happening as the laptop didn't reach the requisite temperatures even during our *Metro Exodus* stress test, staying in the lower 70°C range. Neither did it get warm enough while playing *Cyberpunk 2077*. This feature may still have value in warmer environments where the laptop's cooling system would have to work harder, but it's hard not to be disappointed at this first implementation.

Lenovo will rightly point out that this system is always near the top of the speed graphs (turn to p56) even if it doesn't need to play the liquid cooling card, but that speed comes at the expense of fan noise.

LEFT Connections at the rear include two Thunderbolt 4 ports and HDMI

style and portability on its side, while sacrificing nothing on performance. Nor can I fault the quality of the keyboard, mouse or screen. If you're willing to pay the price for a do-it-all, go-anywhere gaming laptop, the Legion 9i Gen 8 is a truly outstanding machine. **CHARLES JEFFERIES**

SPECIFICATIONS

24-core (8 P-cores, 16 E-cores) Intel Core i9-13980HX processor ● 16GB Nvidia GeForce RTX 4090 graphics ● 64GB DDR5-5600 RAM ● 16in 165Hz mini-LED non-touch panel, 3,200 x 2,000 resolution ● 2 x 1TB M.2 PCI-E Gen4 SSD ● Wi-Fi 7 ● Bluetooth 5.3 ● 1080p IR webcam ● 2 x Thunderbolt 4/USB-C 4 ● USB-A 3.2 Gen 1 ● HDMI 2.1 ● 2.5GbE port ● SD card reader ● 3.5mm headphone jack ● 100Wh battery ● Windows 11 Home ● 358 x 278 x 19-22.7mm (WDH) ● 2.6kg ● 1yr C&R warranty

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Alienware m16 R1

Not the sveltest or the quietest, but still a solid choice for gamers looking to maximise their budget

SCORE ★★★★☆

PRICE As reviewed, £1,416 (£1,699 inc VAT) from dell.co.uk

The Alienware m16 R1 isn't an easy laptop to evaluate due to its customisability. Hurl enough money at Dell and you could build one of the world's most powerful gaming laptops. Instead, our review unit is the entry-level offering, so while its frame rates are poor compared to the Acer Predator (see p56) and Lenovo Legion 9i (see p58), bear in mind it ships with an RTX 4060 chip.

That's matched with Intel's Core i7-13700HX CPU, 16GB of DDR5 RAM and a 512GB SSD, and arguably it's the last that will hold you back. Upgrading to a 1TB SSD costs £50, 2TB £180, and you can go all the way up to an 8TB RAID0 array for an extra £1,119. Other upgrades include a Core i9-13900HX, 32GB or 64GB of RAM, and RTX 4070, 4080 or 4090 graphics. You can even specify the Alienware m16 with an AMD Ryzen 9 7845HX processor.

After such a mind-bending mix of components, it's almost a relief to find only two screen choices. Both are 16in IPS panels, so you choose between a 480Hz 1,920 x 1,200 display or a 165Hz 2,560 x 1,600 unit. Dell sensibly sent the latter, as it offers great clarity while avoiding overkill pixel density.

Those who like the vividness and rich blacks of OLED technology won't fall in love with this screen, but
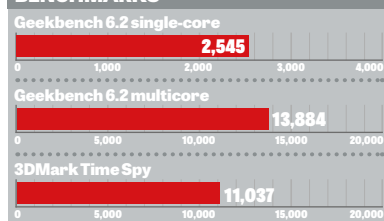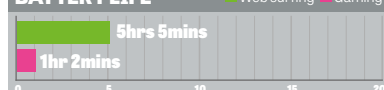
73% coverage of the DCI-P3 means colours look punchy. Accuracy is strong, too, with an average Delta E of 0.15. It would have been nice to go brighter than 290cd/m², though.

Perhaps Dell spent its lighting budget on the keyboard, with the m16's per-key AlienFX RGB effects giving you unlimited options. It's great to type on, with real resonance every time you click and plenty of travel. The touchpad is less joyful to use, with a sluggish feel on occasion.

While I like the m16's aesthetics – its brushed metal finish falls on the right side of premium – it's a chunky beast at 3.3kg. Even the lid is heavy: without a divot to hook your fingers into, opening the Alienware m16 can feel like trying to prise open a particularly stubborn clam. Dell pays attention to the rest of the design, though, with a Dark Metallic Moon colour scheme that proved resistant to fingerprints. Dell sensibly puts most of the ports at the rear, avoiding jutting cables and USB sticks on the left and right. Two Thunderbolt 4 ports are joined by a pair of USB-A connectors, HDMI 2.1 and mini-DisplayPort 1.4 video outputs, an RJ-45 gigabit Ethernet connection, SD card slot and a 3.5mm jack.

The eye-catching vents hint at the cooling within, and they do their job well: all our gaming test results were in line with expectations for an RTX 4060 machine. I ran *Forza Motorsport 8* and *Alan Wake 2* at 1600p above 60fps with little reduction in quality thanks to DLSS 3.

ABOVE Typing the light fantastic: the m16's keyboard feels as good as it looks

"The eye-catching vents hint at the cooling within, and they do their job well: all our test results were in line with expectations"

LEFT Ports include two Thunderbolt 4 and two USB-A slots, all sensibly at the rear

BELOW The m16 is a chunky yet attractive laptop, with striking cooling vents

In general use the Core i7 chip holds its own against Core i9 and Ryzen 7/9 configurations. Only its SSD disappoints, copying a mixed folder of 25GB files at 785MB/sec rather than the 1,800MB/sec or better we're used to seeing from gaming laptops.

The worst element of the m16 is noise. Even seemingly undemanding tasks, such as downloading a game from Steam, can cause the fans to ramp up. Despite this, I don't recommend cradling the m16 on your laptop, as it hit a toasty 49°C in our tests. At least battery life was unaffected, falling in line with our expectations for a gaming laptop.

Sticking with mild disappointment takes me to the webcam. Despite being 1080p, retaining finer image detail is not this webcam's strength. Even in my bright home office it produced pictures that looked muddy.

But let's finish on a strength, for this laptop has one of the best speaker setups I've tested. Not only does it go loud but the soundscape is well balanced, without a hint of the tinny quality you hear on thinner laptops. Bass is deep enough to make listening to music a pleasure, too.

So where does this leave the Alienware m16? Weirdly attractive, despite its heft, and way too loud during the most unexpected, dull computing tasks. It's a machine I both respect and am puzzled by. If I had a budget over £2,000, I wouldn't consider it. However, at £1,699 for this spec – and with Nvidia's AI learning techniques to help boost rates – it makes for a compelling "budget" gaming laptop. **DAVE MEIKLEHAM**

SPECIFICATIONS
24-core (8 P-cores, 16 E-cores) Intel Core i7-13700HX processor ● 8GB Nvidia GeForce RTX 4060 graphics ● 16GB DDR5-4800 RAM ● 16in 165Hz IPS non-touch panel, 2,560 x 1,600 resolution ● 512GB M.2 PCI-E Gen4 SSD ● Wi-Fi 6E ● Bluetooth 5.3 ● 2 x Thunderbolt 4/USB-C 4 ● 2 x USB-A 3.2 Gen 1 ● HDMI 2.1 ● mini-DisplayPort 1.4 ● gigabit Ethernet port ● SD card reader ● 3.5mm headphone jack ● 86Wh battery ● Windows 11 Home ● 369 x 290 x 25.4mm (WDH) ● 3.3kg ● 1yr Premium on-site warranty

BENCHMARKS

Geekbench 6.2 single-core
2,545
| 0 | 1,000 | 2,000 | 3,000 | 4,000 |

Geekbench 6.2 multicore
13,884
| 0 | 5,000 | 10,000 | 15,000 | 20,000 |

3DMark Time Spy
11,037
| 0 | 5,000 | 10,000 | 15,000 | 20,000 |

BATTERY LIFE
● Web surfing ● Gaming

5hrs 5mins
1hr 2mins
| 0 | 5 | 10 | 15 | 20 |

Lenovo ThinkPad E14 Gen 5 (Intel)

A great choice for business users who seek a high-quality slim laptop on a budget, but choose the bigger battery

SCORE ★★★★☆

PRICE As reviewed, £835 (£1,002 inc VAT) from lenovo.com

Despite its competitive price – the range starts at £649 inc VAT for a Core i3-1315U/8GB/256GB spec with Windows 11 Home – the E14 Gen 5 is everything a ThinkPad is expected to be. This graphite black laptop has the chrome ThinkPad logo on its aluminium lid, complete with the red-lit dotted "i" that gives it a hint of business elegance.

I tested the version with a polycarbonate/ABS cover, but you can choose aluminium. This adds nothing to the price and only 20g to the weight, and the latter is one of this laptop's most attractive features: 1.4kg with the 47Wh battery, 1.5kg with the 57Wh option. However, with the bigger battery in place, the laptop only survived 7hrs 48mins in our web-surfing test. With this spec, we expected something over nine hours.

The power drain doesn't come from Lenovo squeezing every last drop out of the supplied Core i7-1355U CPU. Although the E14 Gen 5 never missed a beat in my daily usage, the benchmarks don't lie: Lenovo's own ThinkPad X1 Carbon Gen 11 (*see issue 350, p85*) scored 8,979 in Geekbench 6.2's multicore test to the E14's 8,000. Similarly, in our Handbrake test, the E14 took 10mins 57secs to convert our sample 4K video to 1080p compared to 9mins 5secs for the X1.
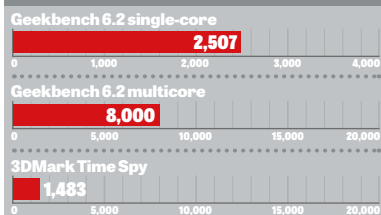
Both machines have 16GB of RAM and, while the X1 has the advantage of LPDDR5 memory, it's all soldered onto the motherboard. Here, 8GB is soldered on but there's an 8GB DIMM that can be replaced by a 32GB module. You can also swap out the supplied 512GB SSD, a short but speedy M.2 2242 unit, or specify a 1TB model for an extra £60 when ordering.

The E14 continues Lenovo's tradition of excellent keyboards, with snappy, deep-travel, chiclet-style keys, the trademark red TrackPoint and plenty of spacing. I loved typing on it and managed 91 words per minute in the **10FastFingers.com** test with 97% accuracy, compared to my average of 88wpm with 91% accuracy. A smooth and centrally located touchpad adds to its attractions.

As ever with budget laptops, Lenovo has made a sacrifice with the screen. This is no wide-gamut affair, covering 65% of the sRGB space and 46% of DCI-P3. However, it's strong in other areas: peak brightness of 374cd/m² is actually 74cd/m² more than Lenovo claims, while an average Delta E of 0.3 confirms excellent colour accuracy. It's anti-glare, too, so great for office work, while a 1,920 x 1,200 resolution looks sharp over the 14in diagonal.

A webcam perches above the screen, and it's worth choosing the 1080p unit in my machine over the 720p option (at a cost of £20). It produced excellent video in good lighting, and even coped in low-light conditions. Autofocus and tracking were speedy, while using Windows Hello proved a breeze.

The dual mics did a fine job of focusing on my voice while keeping background noise to a minimum, and I was similarly pleased with the speakers. Music emerged with discernible depth, mid-tones and highs. Take Megan Thee Stallion's "Her". The house music bassline hit hard, with no distortion even at the highest volume.

Despite being lightweight and pretty slim – 19mm at the front, 22.7mm at the rear – Lenovo includes a generous number of ports. The left side packs two Thunderbolt 4 ports, a USB-A port, an HDMI out and a combo audio jack. The right features a USB-A port, gigabit Ethernet and a nano Kensington lock. The latter adds to an impressive roster of security features, with a physical cover on the webcam, a self-healing BIOS and the option of a fingerprint reader (£10) built into the power button.

Our price includes all these options, including Windows 11 Pro, but one of the great things about Lenovo's approach is that you can customise it. For example, switching to a Core i5-1335U saves £200. You might prefer to spend some of this to extend the one year of on-site cover to three years; this has a list price of £210, but Lenovo frequently offers generous discounts.

So while battery life disappoints and we have criticisms of the screen and its outright speed, the E14 Gen 5 adds up to a strong choice for businesses on a budget. And even if you do cut it down to its most basic specs, it will exude professionalism for years to come. **MARK ANTHONY**

> **"There's an 8GB DIMM that can be replaced by a 32GB module. You can also swap out the supplied 512GB SSD"**

ABOVE The ThinkPad E14 is an excellent choice for business environments

LEFT The excellent keyboard makes speedy typing for long periods a breeze

BELOW Ethernet and plentiful USB ports make this a fine workhorse

BENCHMARKS

Geekbench 6.2 single-core
2,507

| 0 | 1,000 | 2,000 | 3,000 | 4,000 |

Geekbench 6.2 multicore
8,000

| 0 | 5,000 | 10,000 | 15,000 | 20,000 |

3DMark Time Spy
1,483

| 0 | 5,000 | 10,000 | 15,000 | 20,000 |

BATTERY LIFE

Web surfing 7hrs 48mins

| 0 | 5 | 10 | 15 | 20 |

SPECIFICATIONS

10-core (2 P-cores, 16 E-cores) Intel Core i7-1355U processor ● Intel Iris Xe graphics ● 16GB DDR4-3200 RAM ● 14in 60Hz IPS non-touch panel, 1,920 x 1,200 resolution ● 512GB M.2 PCI-E Gen4 SSD ● Wi-Fi 6 ● Bluetooth 5.3 ● 1080p IR webcam ● Thunderbolt 4/USB-C 4 ● USB-C 3.2 Gen 2 ● USB-A 3.2 Gen 1 ● USB-A 2 ● HDMI 2.1 ● gigabit Ethernet ● 3.5mm jack ● 57Wh battery ● Windows 11 Pro ● 358 x 278 x 19-22.7mm (WDH) ● 1.4kg ● 1yr on-site warranty
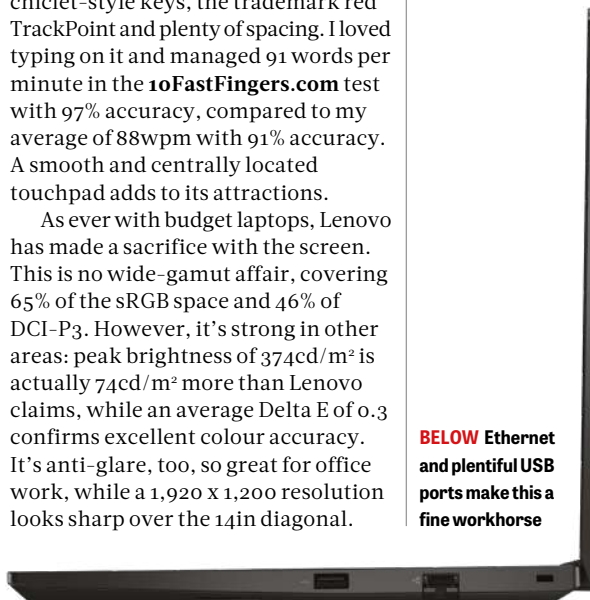
Bag a software bargain

Don't pay full price for software when we can offer you huge reductions on everything from Photoshop Elements to Windows 11 Pro

Adobe Photoshop Elements 2024 for just £59.99 (2 devices, perpetual licence)

🌐 tinyurl.com/elements2024

Photoshop Elements 2024 is the latest edition of Adobe's popular consumer version of Photoshop, and we have a deal that will save you £27 from its normal £86.99 price and give you two licences. And don't worry if you're a Mac user: simply select the Mac version of the software for the same price.

The program is built around Sensei AI technology, which takes the hassle out of editing by providing a series of "guided edits" to simplify popular tasks. That could be automatically colourising old black and white photos, replacing backgrounds to add more vibrancy, or making one-click selections of awkwardly shaped objects.

Throw in tools for removing unwanted objects and combining two shots into a single photo, and the sky is almost literally the limit (speaking of which, you can easily replace that too if it's dull and uninspiring).

One major new feature is the ability to transform a static photo into a moving image with one click. This makes use of both 2D and 3D camera motion, again powered by Adobe's Sensei AI tech, to generate striking animated GIFs.

Users also gain a step-by-step tool for moving, scaling and/or duplicating objects, along with the ability to tweak the position of people's faces to ensure they're "looking" in the right direction.

The app's Catalog tool – which includes albums, keyword tags, people, locations and more – is now automatically backed up too, ensuring none of your hard organisational work will go to waste.

SAVE 31%

ALSO CONSIDER Adobe Photoshop Elements & Premiere Elements bundle for £99.99 **SAVE 27%**

Upgrade to Windows 11 Pro for just £49.99

🌐 tinyurl.com/pcprowin11

If you're using Windows 11 Home but fancy switching to Professional, we have great news. Not only is it a steal at £49.99, but it's incredibly simple to do. Upgrading is a matter of typing "Change product key" and then entering your new Pro licence key into the dialog box. Windows will then update and reboot, and you'll see a fully activated Windows 11 Pro.

Within minutes, you'll have access to extra business functionality: enhanced BitLocker encryption, remote logins and more. Perhaps best of all, you can create and host virtual machines using Hyper-V, which is ideal for testing new software or, if you're a developer, checking how your software performs on other OSes.

Windows 11 Pro also enables you to quickly connect to a domain – this could be your business or a school – to access network files, servers and printers. It's ideal for taking your work on the road when you still need access to the office network.

SAVE 58%

ALSO CONSIDER Avast Ultimate 2023 (10/2yrs) for £29.99 **SAVE 85%**

Acronis Cyber Protect Home Office 2023 Advanced for £29.99 (1 device, 1 year, 50GB storage)

🌐 tinyurl.com/pcprocyber

Acronis Cyber Protect has one simple aim: to protect your data from any threat. That means you get backup, disk cloning, cyber protection and privacy tools in a single package.

Advanced backup and disk cloning sit at this product's core. You get flexible backups, from full drive images to individual files, and clever incremental and differential options encourage daily backups without filling your storage. You also receive active disk cloning for migrating to faster or bigger hard drives. Perhaps most reassuringly, you benefit from Acronis' unique ransomware protection, too.

The Advanced version packs in a whole heap of extra features, including antivirus and anti-malware to protect your computer and your backups.

The £29.99 price, a 23% saving over the full £38.99 cost, includes a one-device licence for either a PC or Mac with a one-year subscription and 50GB of cloud storage.

SAVE 23%

ALSO CONSIDER Norton 360 Premium for £19.99 **SAVE 89%**

Anycubic Kobra 2 Pro

User-friendly features and exceptional speed make this a great choice for beginners

SCORE ★★★★☆

PRICE £233 (£279 inc VAT)
from amazon.co.uk

The Anycubic Kobra 2 Pro is a significant upgrade over the regular Kobra 2 (*see issue 347, p68*). The most notable improvement is to printing speed: the Kobra 2 was already fast, with a top speed of 300mm/sec, but the Pro raises this to a swift 500mm/sec. It also includes a faster 1.2GHz Cortex-A7 processor, plus a new tool head with a refined direct extruder and structure, intended to produce smoother prints.

Like all Kobra 2 printers, it's an open-frame Cartesian design, which makes it easy to access your models; it's educational, too, as all its workings are on display. With a print area of 220 x 220 x 250mm you can make sizeable models.

Once assembled (a ten-minute task), the printer calibrates itself. You're then ready to use it, which is made beautifully easy by a 4.3in LCD touchscreen. This allows you to quickly access and modify print settings, monitor ongoing jobs and control the printer.

The Kobra 2 Pro has 8GB of internal storage, so you can import models from a USB flash drive or SD card, store them on the machine and churn out copies with the touch of a few buttons. For preparing your own models, custom AnycubicSlicer software is very accessible for beginners; or you can use industry-standard applications such as Cura.

As soon as you kick off your first print you'll appreciate the Kobra 2 Pro's standout feature: the fast CPU and optimised direct extruder work together to achieve remarkably rapid filament delivery. Not only does this mean models arrive sooner than they do with other budget 3D printers, but the smoother operation leads to a significant reduction in layer lines.

Reliability is excellent, too, thanks partly to Anycubic's LeviQ 2 levelling system. This uses an inductive sensor to check 25 points across the print platform and compensates for any surface irregularities: it delivered a perfect first layer every time. To further ensure successful prints, the Kobra 2 Pro includes a filament run-out sensor and will pause the print so you can fit a new spool and continue.

I'm delighted to report that throughout my testing, the Kobra 2 Pro successfully printed a variety of models from Anycubic, along with downloaded models and user-created designs, without a single failure. At first I encountered minor dimensional accuracy issues, but these were swiftly rectified by adjusting the belt tensions, as clearly guided by the user manual.

And the Kobra 2 Pro isn't just about speed. The printer's exceptional fine flow control makes it adept at managing intricate details and producing smooth surfaces. With an average error margin of only 0.128mm, it's ideal for model makers and product designers who demand precise dimensional accuracy – or, thanks to the printer's proficiency with bridges and overhangs, it could be used for architectural models and functional parts in product design. It works with a wide range of materials, too, with support for PLA, ABS, PETG and TPU. I tried a selection of different filaments and saw minimal stringing and excellent layer adhesion.

There are potential drawbacks. There's no built-in video monitoring (although you can plug an external camera into one of the three front-facing USB ports), and the open design isn't ideal for all environments: the extrusion head gets very hot, and the accompanying fan is downright noisy when printing at top speed.

Overall, though, the Kobra 2 Pro is a fast, reliable and versatile 3D printer. Novices will appreciate the user-friendly interface, while its quality and precision will appeal to more dedicated hobbyists, crafters and product designers. **ALASTAIR JENNINGS**

ABOVE The Kobra 2 Pro prints impressive 3D models in no time

LEFT Look and learn: all the workings are on display

> **"Throughout my testing, the Kobra 2 Pro successfully printed a variety of models without a single failure"**

BELOW Adjustments are easy thanks to the user-friendly manual

SPECIFICATIONS
Fused deposition modelling (FDM) print technology ● up to 500mm/sec print speed ● 4.3in LCD ● 220 x 220 x 250mm build area ● supports PLA, TPU, ABS, PETG ● 435 x 463 x 486mm (WDH) ● 8.4kg ● 1yr limited warranty

Your bonus software

We scour the globe to negotiate the best software deals for our readers, from extended licences to full programs you don't need to pay a penny for. Here's this month's lineup

O&O Defrag 25 Professional

O&O Defrag 25 is a powerful and highly configurable hard drive defragmentation package. At launch it presents a list of all the drives attached to your PC; selecting one displays the usual mosaic-style map of its file layout. Now, click Start, and watch as O&O Defrag reorganises the data to achieve maximum possible performance.

■ **Full product worth £30**
■ **oo-software.com**
REQUIRES
Windows 10 or later; 120MB hard drive space; online registration

This is just the start, though. If you have multiple hard disks, select as many as you like and the program can defragment them all, simultaneously.

Optimising your drive not only helps your PC to run more quickly, it can also extend the life of the drive. By restructuring your files so they're laid out in a logical order, you can save the drive from spinning so much, and the head from hunting back and forth as it gathers together the fragmented pieces of each file you access. Ultimately, your drive can spend more time resting and less time working.

Moreover, should your drive ever become corrupted, you'll have a greater chance of recovering your files using data recovery software if they are contiguous, rather than scattered in pieces across the disk's various platters.
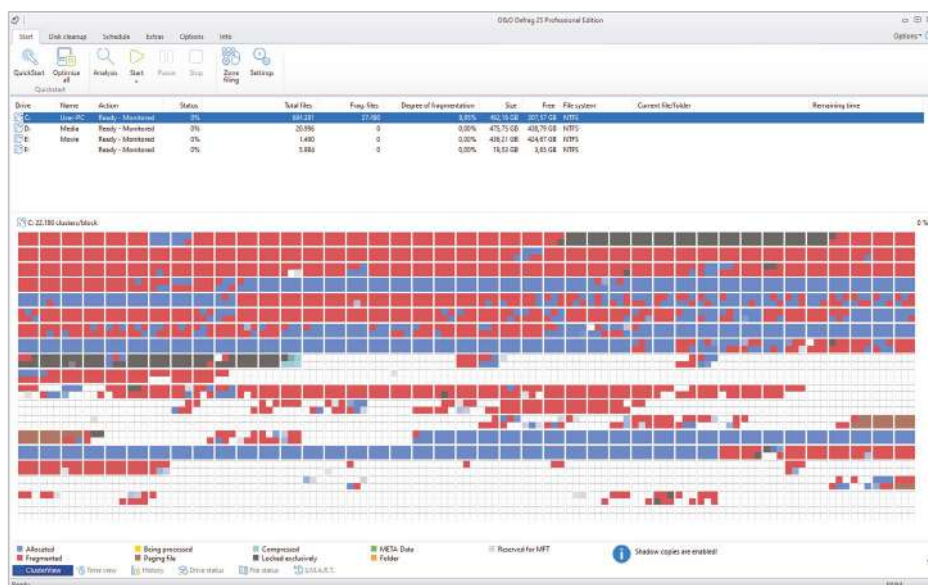
You're not limited to a one-size-fits-all defrag strategy. You can have your files organised by their name, access date, last modified date or other criteria to suit your needs. Or, if that's still not quite right, you can set up an entirely custom scheme that organises your Windows folder, application files and user data according to your preferences, to deliver the best possible system performance.

The first time you run a defragmentation process it may take a little longer than you expect – that's because the program needs to work its way through the whole file system and shuffle your files into their best possible positions. Subsequent operations should be completed more quickly. When O&O Defrag finishes its task, it presents a report so you can see exactly what it's done.

Despite its powerful capabilities, O&O Defrag is easy to use. Once you've set it to work as you'd like, it will mostly run in the background, defragmenting your hard drive automatically as required while you get on with other things. It can also be configured not to run if your system is busy or when other heavy-duty programs are running – so it won't ever get in your way when you're working.

ABOVE You can set O&O Defrag to run to your preferred schedule, to ensure your hard drives are kept in tip-top condition
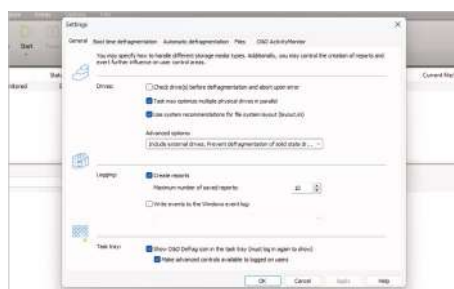
ABOVE Extensive settings let you customise features such as boot-time defragging and automatic activity throttling
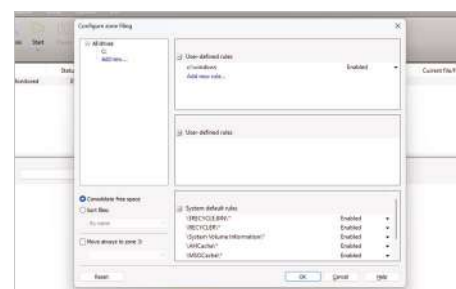
ABOVE Take full control of your hard disk layout by organising system files, applications and personal folders into separate zones

WebCam Guard

- This simple tool gives you full control over your webcam, allowing you to turn it off when not in use
- Optionally disables your microphone to ensure you're not overheard if an audio connection is left open
- Blocks unwanted webcam and microphone access through a specially designed algorithm

- **Full product worth £25** ■ ashampoo.com **REQUIRES** Windows 10 or later; 50MB hard drive space; in-application registration

Find My Files 2023

- Speed up the process of locating specific files when searching your computer
- Use filters to narrow down the list of results until you find the exact file or group you're looking for
- Browse recently used files and important file information using forensic data-search methods
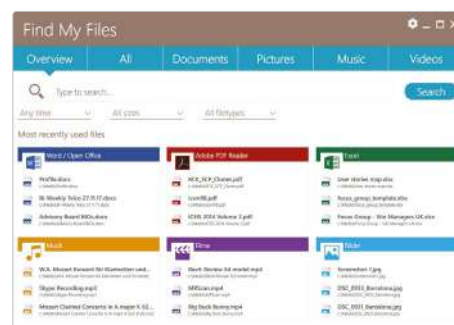
- **Full product worth £30** ■ abelssoft.net **REQUIRES** Windows 7 or later; 50MB hard drive space; online registration

Audials Radio Edition 2024 SE

- **Full product worth £35** ■ ascomp.de **REQUIRES** Windows 7 or later; 3GB hard drive space; online registration

- The easy way to find radio stations online
- Search for stations by name, or filter according to your musical tastes
- Add stations to a list of favourites, make recordings and search for the tracks they play

Ascomp PDF Imager 2

- **Full product worth £13** ■ ascomp.de **REQUIRES** Windows 7 or later; 10MB hard drive space; in-application registration

- Convert PDF files into a range of image formats, with support for JPEG, PNG, TIFF and more
- Convert multi-page PDFs or single pages
- Once converted, open the results in an image editor to easily add a signature

IObit Smart Defrag 9 Pro

- **Six months of updates worth £10** ■ iobit.com **REQUIRES** Windows 7 or later; 50MB hard drive space; online registration

- Flexible tool to optimise individual files or your whole hard drive
- Launch on demand, or set it to run in the background – using less than 15MB of RAM
- Also includes boot-time defrag technology

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2 Once you're in the download area, you can access this month's bonus software by navigating to the relevant product page and clicking the red Install button. For trial software, freeware and other downloads, click the Install button below the product description, or follow the onscreen instructions (please make sure to read these carefully).

3 If the software needs registering, click the purple Register button, or follow the instructions on the left of the product page (again, please read these carefully). In some cases, you may need to register for a *PC Pro* software store account – if you don't already have one – and you might be prompted to reenter the coupon code on the spine or cover.

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Remember to claim your software by 29 February 2024 *

pcprodownload.co.uk

Wacom One 13 Touch

You can buy bigger drawing tablets for less, but the build quality, ease of use and stylus make this stand out

SCORE ★★★★☆

PRICE £483 (£580 inc VAT)
from scan.co.uk

The Wacom One 13 Touch is the latest drawing tablet from one of the best-known names in the business. It's a follow-up to the 2020 Wacom One, and is positioned as the new flagship model of Wacom's affordable drawing tablet range.

As a result, aspects of the design feel quite luxurious, while others smack of cost-cutting – for example, the glass screen feels premium, while the rest of the white casing is plastic. However, it looks tasteful, and is less prone to fingerprints than a pricier metal model would be.

In fact, the tablet as a whole looks and feels great to hold. It weighs a mere 900g and measures only 12mm thick, with generous bezels ensuring your mitts don't intrude on the screen. That's just as well, as it lacks a built-in stand, so if you're not happy holding it up you'll need to find a separate solution.

The Wacom One 13 Touch is beautifully simple to set up. Two USB cables are included, for connecting to a computer and a power supply, but I had no problem using a single cable to power the tablet from my laptop. Once you're hooked up, all you need to do is head to the Wacom website, download the right driver for your operating system, customise the stylus' two buttons to your ideal specification, and start drawing.

Almost immediately, you'll notice one area where the One 13 Touch is a big improvement on the old Wacom One. The display itself is the same size, measuring 294 x 165mm with a 16:9 aspect ratio. However, it now goes up to a maximum of 320cd/m² – much brighter than its predecessor, which sometimes looked a little drab. The contrast has also been boosted from 1,000:1 to 2,000:1, ensuring lights and darks stand out clearly from each other, and the panel covers 99% of the sRGB colour space.

The compromise is that the screen is still stuck with a native 1080p resolution. That's no surprise considering the price, but it's a shame not to get more detail on a 13in screen. It's fine for sketches, but intricate professional commissions might call for something with a higher pixel count. The stylus, meanwhile, is really something of an achievement. Although it's a lightweight, battery-free plastic pen, it still offers 4,096 levels of pressure sensitivity and even looks good doing it. There's a range of customisable colour options to choose from when buying from the Wacom website, and you can also decide whether you want your stylus to have a small clasp to attach to a pocket. In all pen models you can thread a thin string or cable through the end, to tether it to the tablet and ensure it never gets lost; if you don't, you can still slide the stylus into a loop at the top of the tablet for storage and transportation.

The stylus runs easily across the screen, with good recognition of tilting and pressure for heavier or thicker markings. My overall impression is "smooth". I felt it wasn't quite as sensitive as pricier pens that support 8,192 pressure levels, but it should be fine for casual artists.

The stylus also has two configurable buttons along its side, which are handy for activating the

ABOVE The 1080p screen lacks detail but is bright and colour-accurate

LEFT The lightweight stylus offers 4,096 levels of pressure sensitivity

> **"It supports multitouch gestures, so you can use one or more fingers to scroll, pan and zoom during the creative process"**

BELOW There are two USB-C ports, but in most cases you'll only need one

eraser function, switching to a secondary colour or navigating the scroll and zoom options during the creative process. It's a simple stylus, but it covers the basics, and comes with a pack of replaceable nibs, for when one starts to blunt after extended use.

Appealing though the stylus is, one of my favourite things about the Wacom One 13 Touch is that you don't need the pen for navigating the page and controlling your drawing software. As the name hints, the tablet supports multitouch gestures, so you can use one or more fingers to scroll, pan and zoom during the creative process. It's much more convenient and natural than using the stylus, or switching back and forth between the tablet and your computer, but if you find the touch sensitivity distracting, you can turn it off by flicking a switch on the top of the tablet.

For anyone starting out in the world of drawing tablets, there are plenty of options to choose from. Wacom itself offers a bewildering number of models at various prices and with different features, and you can buy a larger tablet for less from rivals such as XP-Pen. However, the Wacom One 13 Touch is a wonderful pick-up-and-use option, with a light build and a simple single-cable connection – and the inclusion of multitouch gesture controls really sets it apart from the crowd. **HENRY ST LEGER**

SPECIFICATIONS
13.3in drawing display (IPS touchscreen panel) ● 1,920 x 1,080 resolution ● typical 250cd/m² brightness ● 2 x USB-C ports ● Wacom stylus ● 336 x 12 x 222mm (WDH) ● 900g ● 2yr limited warranty
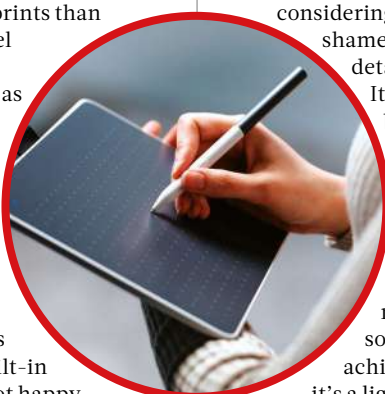
XP-Pen Artist Pro 16 (Gen 2)

A stylus with 16,000 pressure levels makes this second-generation drawing display a compelling choice

SCORE ★★★★☆

PRICE £441 (£530 inc VAT)
from storexppen.co.uk

Like the Wacom One 13 Touch opposite, the Artist Pro 16 Gen 2 is a drawing tablet – and one with high-end features that will more than justify the price for serious artists.

While the first model was a chunky grey affair with built-in buttons, this version has a sleeker, cleaner design, with the controls moved onto a compact wireless remote. This features ten customisable shortcut buttons, plus a programmable circular dial, and it allows you to be productive with both hands as you work.

The only visible feature on the tablet is a wrist support beneath the screen. This doesn't have much in the way of cushioning, though, and it only really helps when you're drawing on the lower half of the screen. At the back are two kickstands, which can either recess into the body or fold out to prop up the screen at a fixed 19° angle.

Buttons for power and brightness sit on the upper edge of the tablet, plus two USB-C ports for connections to your computer and a power supply. You can also hook up a three-way cable (sold separately) that offers USB-A, USB-C and HDMI connectors.

The screen has a sharp 2,560 x 1,600 resolution, giving a comfortable 16:10 aspect ratio. A 250cd/m² brightness is plenty for studio work, and anti-glare glass keeps reflections to a minimum. I also appreciated the fine 100-point brightness control, which enabled me to make precise adjustments as the sunlight gradually vanished over the course of an evening. You can also turn off the display and use the Artist Pro 16 as a classic screenless tablet. Colour performance is impressive for the price, with 99% coverage of the

sRGB and DCI-P3 colour spaces, and 97% coverage of Adobe RGB.

Setup is easy: install the driver from the XP-Pen website (Windows, macOS and mobile platforms are all supported), configure your pen and fire up your chosen drawing software.

Drawing on the screen is smooth and instantaneous, and since the front glass of the Artist Pro 16 Gen 2 is laminated directly onto the LCD panel, markings appear precisely where you place your pen, with none of the frustrating misalignment problems you can get when using a stylus on a regular tablet screen. Nor did I encounter any issues with lag or judder, while the shortcut remote worked perfectly for switching quickly between functions – it's an enjoyable and efficient way to work.

The stylus itself is XP-Pen's best yet. Dubbed the X3 Pro Smart Chip Stylus, it claims sensitivity to 16,000 pressure levels – roughly double the 8,192 supported by most drawing tablets. It's brilliantly responsive, and you need not worry about losing the nuances of stroke widths and shading.

It feels nice in the hand, too, with a rubber grip that ensures it won't slip from your fingers, and two built-in buttons that can be customised for a multitude of functions. At the top, a rounded edge acts as a digital eraser, which worked well for quickly touching up my creations.

ABOVE The Artist Pro 16 Gen 2 is packed with high-end features

PC PRO RECOMMENDED

"The stylus is XP-Pen's best yet. It claims sensitivity to 16,000 pressure levels – double the 8,192 supported by most drawing tablets"

The stylus is battery-free and there's a sleek black case for storage. Push in the drawer from one side and it releases, exposing the stylus and eight replacement nibs: four standard nylon ones, which should keep you going for a while, and four felt alternatives for those who prefer a softer feel. The case also includes a USB Bluetooth adapter, for linking your computer to the shortcut remote, although my laptop connected directly to it without issue.

The XP-Pen Artist Pro 16 Gen 2 feels like a highly professional product, but there are a few things that cheapen it. One is a slight lack of friction between stylus and screen; it doesn't have the pen-to-paper feel of more expensive tablets, even with the felt nibs. It's a shame, too, that the built-in stand doesn't offer any adjustment. I found the preset angle worked well enough for sketching, but if you want it steeper or shallower you'll need to prop it up on something – or pick it up and hold it in one hand while you sketch with the other.

Despite those minor flaws, the XP-Pen Artist Pro 16 Gen 2 is an excellent drawing tablet for hobbyists and early-career professionals. Its big, sharp, responsive screen makes drawing a pleasure, the sleek accessories and streamlined controls help you jump right into creativity with minimal fuss and, considering what you get, the price is extremely competitive. **HENRY ST LEGER**

SPECIFICATIONS
16in drawing display (IPS touchscreen panel) ● 2,560 x 1,600 resolution ● 19° tilt ● typical 250cd/m2 brightness ● accuracy ±0.4mm centre, ±0.8mm corner ● 2 x USB-C ports ● X3 Pro Smart Chip Stylus ● wireless shortcut remote ● 405 x 20.2 x 291mm (WDH) ● 2yr limited warranty

LEFT A slick travel case means you shouldn't lose the stylus or spare nibs

Carrera Smart Glasses with Alexa

Still US-only, but we're finally starting to see reasons to buy Amazon's third-generation smart glasses

SCORE ★★★★☆

PRICE $390 from amazon.com

After the Ray-Ban Meta Smart Glasses last month (*see issue 352, p71*), it's Amazon's turn to lure people to wear smart glasses. But only in America. Our cousins are now on their third generation of Amazon Echo Frames, with a collection of colours and frame styles that make the Alexa-equipped glasses far more approachable than before.

Prices start at $270, a $20 jump from the previous-gen pair, and there are also premiums for lens and frame styles. The most basic sunglasses cost $330, for example. There are also two separate sunglasses styles designed with Carrera, as I test here, with an accompanying jump in price.

Whichever version you choose, the Echo Frames look like a normal pair of glasses. In fact, nobody I met seemed to suspect my shades were packed with tech. That wasn't the case with the Ray-Bans, which have cameras clearly jammed into the front corners of the frame. Wearing the Echo Frames felt natural as well, with a balanced weight and a comfortable fit.

A rocker for adjusting the volume sits underneath the left frame, with two control buttons underneath the right. These buttons can be assigned functions in the device settings in the Alexa app. You can mute the microphones by double-tapping the front control button, too.

So, what can these glasses do? At their most basic, control music playback and answer calls. Alexa can now also filter notifications, so you're only alerted to important messages from people on your so-called VIP list.

Otherwise, Alexa acts as a virtual butler, ready to answer questions as it would through any Alexa-enabled speakers or screens. Typically, I asked it for weather reports, sports results and for a reminder of the items on my to-do list. The catch? These helpful queries are only available when your connected device has internet service.

In terms of new features, the Echo Frames now have multi-pair support, letting you connect simultaneously to multiple devices. This means being able to switch from a video call on your laptop to music on your smartphone without having to mess with the connectivity settings; however, since I was testing sunglasses, I only wore them while outdoors. Therefore, I only ever connected them to my phone. If I were to buy a pair, I would opt for clear lenses so I could use them inside, too.

They have a neat location-detecting feature, too. If you misplace them, ask Alexa on another device to "find my smart glasses", and you'll be told their last known location. As someone who always loses their sunglasses, this is a game-changer.

As mentioned, the glasses let you listen to music discreetly thanks to the speakers built into the frames. Audio quality was an area Amazon definitely needed to improve on, and the new custom-built speaker driver successfully delivered stronger bass. The glasses can't compare to my Sony WH-1000XM5 headphones or AirPods, but for passive listening on a commutes they sound punchier than you'd expect.

That said, I'm still concerned about audio spillage. When I

ABOVE On the outside the Carrera Smart Glasses appear to be normal sunglasses

> **"The Echo Frames look like a normal pair of glasses. In fact, no-one I met seemed to suspect my shades were packed with tech"**

LEFT The Echo Frames feel natural to wear, with a comfortable fit

BELOW Buttons on the frame control volume and can be assigned functions

was sitting at my desk, nearby colleagues could hear the synths of Kate Bush's "Running Up That Hill" coming from my general vicinity with the speakers at half volume.

During phone calls, I could hear the person on the other end clearly when I wasn't in a particularly noisy place. They said they could hear me fine in this scenario, too. But when I was walking through a windy park, phone call quality suffered. Ray-Ban's glasses offer superior call quality in all environments, but the Echo Frames suffice for the occasional conversation.

In terms of battery life, you can expect six hours with continuous music playback at 80% volume. But it's important to note that battery life varies, with the glasses lasting longer in a standby mode if you're not listening to music or speaking with Alexa. My frames kicked into standby mode when I left them in the included carrying case, but sadly this doesn't double as the charger (as is the case for the Ray-Ban Meta Smart Glasses). Instead, the Echo Frames charge via a charging base with a bridge structure. Now, I thought anything would be an improvement to the magnetic charging cord from the previous model, but I was wrong: you need to place the glasses exactly the right way for them to charge, and I found this took a few tries each time.

Despite this, out of the numerous pairs of smart glasses I've tried, there are only two I can recommend: the Ray-Ban Meta Smart Glasses that let you capture the world through your eyes, and now, the Echo Frames that slap Alexa to your face. I can't offer you any long-term benefits to having Alexa a whisper away, besides a kind of convenience you have to be eager to explore. But if you already have the interest, these glasses are a fun and stylish introduction to the category. **KATE KOZUCH**

SPECIFICATIONS
2 x microspeakers ● 4-mic array ● Bluetooth 5.2 ● IPX4 ● charging stand ● 57-16-147mm measurement guide ● 39g ● compatible with Android 9 and iOS 14 and above ● 1yr warranty

Amazon Fire HD 10 (2023)

Look out for Amazon deals that put the price closer to £100 and this becomes a tempting budget tablet

SCORE ★★★★☆

PRICE 32GB with ads, £125 (£150 inc VAT) from amazon.co.uk

The 13th generation Amazon Fire HD 10 was released too late to be considered in our group test last month (*see issue 352, p76*), but even if it had landed in time it's arguable whether it would have made the cut. That's not because this is a terrible tablet, merely that we were looking for "luxury" devices – and luxury isn't a word I'd apply to the Fire HD 10.

It doesn't feel or look cheap, but a plastic rear and relatively thick 8.6mm chassis betray its budget leanings. While Amazon may list the full price as £160 for the 32GB version (£190 for 64GB), ever since launch it's been selling for around £105 with ads. I certainly wouldn't pay the full asking price when you can pick up the far more stylish Honor Pad X9 (*see issue 352, p89*) for £160.

In terms of outright speed, the two are locked together, which translates into the bottom of the table in our benchmarks. Take our graphics tests, where the Fire HD 10 returned 180 in 3DMark Wild Life Extreme. That's 1.1 frames per second, but don't despair. Purely for the sake of research, I loaded up *Jurassic World: The Game* and, despite the plush, tropical surrounds and rain effects, it played perfectly smoothly. As did *Roblox*. It may not

benchmark well, but this tablet is a match for undemanding games.

Geekbench scores of 696 and 1,787 would again have placed the Fire HD 10 near the bottom of the table in our Labs, and that trend continued throughout our phalanx of tests: 56 in WebXPRT 4, 52 in JetStream 2, 1,934 in MobileXPRT 3. Unfortunately, this translates into plenty of stuttering during real-world use. There are even occasional delays in Amazon's Fire OS interface.

Thankfully, once you launch an app things tend to run much more smoothly. For instance, flicking through pages in the Kindle app is a breeze, while browsing websites in Amazon's Silk web browser is perfectly bearable. To be more precise, there's often a slight hesitation – when switching between tabs or calling up the onscreen keyboard, for example – but you would need to have serious patience issues to be annoyed. Sure, if you're used to a 120Hz display on your phone then you'll also find the 60Hz panel here jolting, but let's remember the price of the tablet.

When watching videos, there are no such worries. They play smoothly and look great on the 10.1in IPS panel. It covers 90% of the sRGB gamut and 67% of the DCI-P3 space, and that's reflected in colours just vibrant

ABOVE The Fire HD 10 is a great budget tablet – but not at its RRP

> "Audio is much better than I expected for such an affordable tablet. And the cameras capture colours and details well"

LEFT Videos look great on the 10.1in IPS panel

BELOW Fire OS can be sluggish, but apps run much more smoothly

enough that you don't worry about it. Anything below 60% and panels look drabber. The colours that it can depict are accurate, too, with an average Delta E of 1.43, while brightness peaks at 434cd/m².

Audio is much better than I expected for such an affordable tablet. It makes a fine stab at delivering bass and, while trebles can be harsh, the overall effect is listenable. Buoyed with fresh enthusiasm, I fired up the camera app to check out the video recording. And it's actually decent: you get 1080p videos from the 5MP rear and front cameras, and these capture colours and details well. It will record your voice clearly, too.

There's even the chance to do some real work on this tablet, as Amazon is selling a Bluetooth keyboard case for £53. Amazon didn't send this for testing, but judging from previous models you shouldn't expect deep key travel or any sense of luxury. You can also buy the £35 Amazon Stylus Pen, with a loop in the top of the keyboard case to keep everything together.

While Google Play isn't provided, it will only take you a few minutes to install (no hacking required). Add Google Drive and Docs – or Microsoft 365, which is on the Appstore – and you have a portable productivity machine. And one with respectable battery life, too, lasting for 12hrs 39mins in our web-surfing test with the screen set at 150cd/m².

Is the Amazon Fire HD 10 a great tablet? Absolutely not. Is it worth £150? Again, no. But if Amazon continues to sell it for around £105 – and especially if you can pick up the case for something closer to £30 than £50 – then it's a solid budget buy. Just don't expect slick performance to match that of an iPad. **TIM DANTON**

SPECIFICATIONS

8-core 2.1GHz/2GHz MediaTek MT8186A chipset ● Mali-G52 graphics ● 3GB RAM ● 10.1in 60Hz touchscreen IPS display, 1,920 x 1,200 resolution ● 32GB/64GB storage ● 5MP rear camera ● 5MP front camera ● Wi-Fi 5 ● Bluetooth 5 ● USB-C 2 ● 3.5mm jack ● battery specification not shared ● Amazon Fire OS 8 ● 246 x 8.6 x 165mm (WDH) ● 434g ● 1yr C&R warranty

BENCHMARKS

Geekbench 6.2 single-core

696

| 0 | 1,000 | 2,000 | 3,000 | 4,000 |

Geekbench 6.2 multicore

1,787

| 0 | 5,000 | 10,000 | 15,000 | 20,000 |

3DMark Wild Life Extreme

180

| 0 | 5,000 | 10,000 | 15,000 | 20,000 |

BATTERY LIFE

Web surfing — 12hrs 39mins

| 0 | 5 | 10 | 15 | 20 |

PAPER POWER

62% of the energy used to produce paper and
paper-based packaging in Europe comes from renewable sources.

Source: Confederation of European Paper Industries (CEPI), 2020.
CEPI represents 92% of European pulp and paper production

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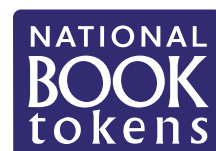
Samsung Galaxy S23 FE

Wedged between powerful flagships and low-cost midrange models, the Galaxy S23 FE struggles to stand out

SCORE ★★★★☆

PRICE 128GB, £499 (£599 inc VAT) from samsung.com

The Samsung Galaxy S23 FE is a real in-betweener. Above it sits the full-fat Galaxy S23 (*see issue 343, p70*), offering all the bells and whistles of a flagship phone for £849; beneath it the Galaxy A54, a great little handset starting at £449. Samsung obviously believes there's a demand for a middle-ground option, but is this really a niche that needs filling?

While the S23 FE looks a lot like the regular Galaxy S23, it doesn't have the same premium feel. There's no Gorilla Glass Victus 2 here – you get Gorilla Glass 5 instead. It's taller and wider than the S23, which makes it harder to hold in smaller hands, and it's 24% heavier. The camera lenses stick out more from the back of the phone, so it wobbles slightly if you try to use the Galaxy S23 FE lying on its back.

On the plus side, you get IP68 water resistance, and the colour options – mint, purple, cream and graphite – are brighter and jollier than the S23's subdued finishes.

The Galaxy S23 FE's display is a dynamic AMOLED panel with a native resolution of 1,080 x 2,340. Its adaptive refresh rate ordinarily runs at 60Hz, but ramps up to 120Hz when there's lots of onscreen activity. It looks bright and smooth, and I had no problem using it outdoors on a bright day, although it isn't as punchy as the excellent screen on the S23. I also found it helpful to turn off adaptive brightness while gaming, as the action sometimes became rather dim.

One area where the S23 FE almost matches the full-price variant is its camera arrangement. Like other S23 handsets, it offers a triple-camera array with a main sensor, plus ultrawide and 3x telephoto lenses. The latter doesn't capture as

many megapixels as on the regular S23 (8MP versus 10MP), but it's unusual for a mid-priced phone to offer a telephoto option at all.

You can take great pictures on the S23 FE, with Samsung's trademark super-vibrant colours; most of my test shots came out looking richer and livelier than the same scenes shot on the Google Pixel 7a (*see issue 346, p68*). However, when the subject matter is already bright and colourful, the Samsung veers towards overexposure: my image of pumpkins at the grocer's was so garishly pumped-up that all detail was lost, while the Pixel 7a captured a much better-balanced shot. The Samsung also falls behind the Pixel 7a when it comes to low-light photography, struggling to resolve detail in murky areas.

I was also disappointed by the S23 FE's telephoto performance. There's still nothing to compare to a "proper" zoom when you want to get close to an object, but there's a fuzziness from this 8MP unit that you don't get from the main 50MP lens. Even though the Pixel 7a lacks a telephoto lens, its zoomed-in images had more detail and an overall crisper appearance. These benefits are achieved with the help of AI processing, so they might not be the truest possible representation of reality – but if you just want nice clean pictures, the Pixel is a better bet than the S23 FE.

The S23 FE might appeal to video fans, though, as it can capture 8K

ABOVE The bright AMOLED panel has a native resolution of 1,080 x 2,340

"The S23 FE is fine for photography, but it's not on a par with the regular S23, and for the price I'd rather be shooting with Google"

ABOVE There's a 3x telephoto lens as well as the main sensor and an ultrawide option

LEFT The S23 FE is taller and wider than the regular S23

video – a feature normally reserved for pricier handsets.

As for performance, the Galaxy S23 FE is built on Samsung's Exynos 2200 SoC. This is now almost two years old, but it's still a powerful chip, and in both CPU and graphical benchmarks the S23 FE pulled ahead of the Pixel 7a and the Galaxy A54. In everyday use the phone performs just fine, with 8GB of RAM proving sufficient to keep things moving smoothly. I never experienced any stutters or delays when playing *PUBG Mobile*, and I could switch between apps in Samsung's One UI OS (based on Android 13) with relative ease.

On that note, an update to Android 14 is imminent, with a further three major version updates promised – just as for pricier Galaxy S flagship phones. That's reassuring, but, unlike the A54, there's no microSD card slot so if you think the standard 128GB of internal storage might not be enough, pay the extra £50 for the 256GB version.

The Galaxy S23 FE's 4,500mAh battery easily lasts a full day of typical use; at a stretch, you might even get to lunchtime the day after. Don't expect super-fast recharge times, though, as it supports a maximum charging rate of 25W, which translates to roughly 1% per minute, and you don't get any sort of charger in the box. On the plus side, it also supports wireless charging at 15W, which you won't find on the Galaxy A54.

If you want something resembling a Samsung Galaxy S23 but cheaper, the Galaxy S23 FE is for you. However, most people will be just as happy with a cheaper phone, from Samsung itself or elsewhere.

And that's the problem with the Galaxy S23 FE: it doesn't have a USP. If you have £600 to spend on a phone then there's nothing wrong with it, but with neither top performance nor a compelling price on its side, it's hard to recommend with much enthusiasm.
PHILIP MICHAELS

SPECIFICATIONS
8-core (2.8GHz/2.5GHz/1.8GHz) Samsung Exynos 2200 SoC ● 8GB RAM ● Xclipse 920 graphics ● 6.4in 120Hz AMOLED screen, 1,080 x 2,340 resolution ● 5G ● 128GB/256GB storage ● triple 50MP/8MP/12MP rear cameras ● 10MP front camera ● Wi-Fi 6E ● Bluetooth 5.3 ● NFC ● 4,500mAh battery ● USB-C 2 connector ● Android 13 with One UI 6 ● 77 x 8.2 x 158mm (WDH) ● 209g ● 1yr warranty

Netgear Nighthawk RS700S

This budget-busting router promises extreme performance over Wi-Fi 7 – but it's ahead of its time

SCORE ★★★★☆

PRICE £667 (£800 inc VAT)
from netgear.com

Last month we reviewed Amazon's Eero Max 7, the first mesh system to support the new Wi-Fi 7 standard (*see issue 352, p68*). Now comes the first standalone Wi-Fi 7 router, a simpler solution for average-sized homes, but that doesn't mean it's cheap. At £800 the Nighthawk RS700S is easily the most expensive router we've ever tested, and £200 more than a single Eero Max 7 unit.

The price difference is partly explained by a much more ambitious hardware specification. Where the Eero advertises peak wireless speeds of 4.3Gbits/sec, the Nighthawk RS700S can connect at up to 5.8Gbits/sec on the 5GHz band, and an enormous 11.5Gbits/sec on the 6GHz band – more than twice as fast as any Wi-Fi 6 or 6E system.

The Nighthawk RS700S is physically imposing, too. It's a tall, monolithic thing, with a bold six-sided design and a row of coloured LEDs down the front that show network status and generally add aesthetic interest. At the back you'll find 10GbE sockets for both WAN and LAN connections, as well as four regular gigabit LAN connectors. There's also a single 5Gbits/sec USB port that you can use for file sharing – as usual with Netgear, it won't support advanced functions such as smartphone tethering or media server duties.

Assessing the performance of the Netgear Nighthawk RS700S is problematic, because the technology is so new that there aren't yet any mainstream Wi-Fi 7-capable laptops available to connect it to. A few high-end smartphones do formally support the new standard, but they're typically limited to a maximum link speed of 5.8Gbits/sec, and further held back by their compact antennas. In short, there's no chance of a phone getting the full benefit of the Nighthawk RS700S's bandwidth.

I confirmed this with a pair of recent phones, namely the OnePlus 11 5G and the Xiaomi 13T Pro. Both could happily establish a Wi-Fi 7 connection to the router, but when I tried downloading files from my local NAS appliance, speeds peaked at around 40MB/sec – fast, to be sure, but hardly groundbreaking.

Indeed, I actually got better results using Wi-Fi 6 and 6E on a regular Windows laptop. At close range I measured download speeds of 95MB/sec over a 5GHz connection, and switching to the 6GHz band raised the data rate to a massive 137MB/sec. Performance at longer range was very satisfactory, too: the RS700S claims a decent coverage area of 325m², and even in the bathroom at the far end of my house I recorded an average download speed of 22MB/sec.

That's more than enough performance for a typical household or office. Most people won't need the extra capacity of Wi-Fi 7 until their home networks grow a lot larger (the RS700S is designed to handle up to 200 clients), and new ultra-high-bandwidth applications such as streaming VR experiences start to emerge.

On that note, it's worth mentioning that the Nighthawk RS700S as currently shipped doesn't support Wi-Fi 7's multi-link

operation (MLO) feature, which aggregates connections across multiple radio bands to further increase bandwidth. That's unlikely to be a problem in the near future – 11.5Gbits/sec ought to be enough for anybody, right? – but it means the very highest peaks of Wi-Fi 7 performance are out of reach, pending a firmware update.

While the Nighthawk RS700S may look futuristic, its web-based management interface is the same one used by every Nighthawk router dating back to 2019. Frankly, I find it ugly and awkward to get around, with too much scrolling and hopping back and forth between different frames and pages. Still, it provides all the important Wi-Fi and network settings, and if you really hate it you can use the Nighthawk mobile app instead. This doesn't offer all the advanced controls of the web console, but it's slicker and more intuitively laid out.

Alongside the standard network controls, the Nighthawk RS700S comes with a year of Netgear's Armor security service (as indicated by the "S" suffix). This includes useful features such as automatic malware scanning, device management and limited use of the Bitdefender VPN. However, once your initial 12 months run out you'll have to pay £85 per year to keep the service going. Parental controls are another optional add-on, costing £50 per annum – so even after you've paid the enormous price for this router, you're looking at considerable ongoing costs to keep it fully functional.

Honestly, at this point I can't say it's worth it. It will likely be six months or more before you have a Wi-Fi 7 laptop – and several years before we're seeing the sort of services that really demand the bandwidth offered by the Nighthawk RS700S. By that time there will surely be many more Wi-Fi 7 routers to choose from, including some at lower prices.

None of this is a criticism of the Nighthawk itself. It's always exciting to witness the first fruit of a new generation of technology, and Netgear deserves credit for getting its debut Wi-Fi 7 router out so rapidly. Unfortunately, the Netgear Nighthawk RS700S is so far ahead of the curve that there's no point in buying it any time soon.
DARIEN GRAHAM-SMITH

> **"It will likely be several years before we see the sort of services that really demand the bandwidth offered by the RS700S"**

SPECIFICATIONS

Tri-band 2.4GHz/5GHz/6GHz Wi-Fi 7 router ● 8 x streams ● 4 x1GbE, 2 x10GbE ports ● USB-A 3.2 Gen 1 ● 2.6GHz quad-core processor ● 124 x 142 x 282mm (WDH) ● 2yr limited warranty

Samsung Portable SSD T5 Evo

Roomier and faster than a portable hard disk, but the street price needs to be much lower than the list price

SCORE ★★★☆☆

PRICE 8TB, £471 (£566 inc VAT) from scan.co.uk

With rated read and write speeds of only 460MB/sec, the Samsung Portable SSD T5 Evo was never aiming for speed awards. Instead, it's about capacity: with 2TB, 4TB and 8TB versions, it's even roomier than most portable hard drives. It has the advantage of being more durable and drop-resistant than such drives, too.

Where it falls far behind is value for money. A 4TB external hard disk such as the WD Elements costs around £110, while the 4TB version of the T5 Evo currently stands at £310 (both prices from **scan.co.uk**). Naturally, the solid-state drive holds a size

advantage over its spinning-disk rival. Sticking to the WD Elements as our example, that measures 21mm thick (4mm more than the T5 Evo) and 111m long, which is 16mm more. But it's width where we see the biggest difference, with 82mm for the hard disk and 40mm for the SSD.

Samsung adds some reassuring toughness to the T5 too, even if it steers away from calling it a rugged SSD. There's no official rating, but Samsung claims the rubberised outer shell gives "extra protection against external shocks", while a thick metal band on one end means you can clip it to a carabiner.

Samsung ships the T5 Evo with a long, removable USB-C to USB-C cable measuring about 40cm. No USB-C ports? Then you'll need to buy a second cable, as Samsung doesn't ship an adapter in the box, which is stingy. Just ensure you buy one that's at least rated to this drive's 5Gbits/sec USB 3.2 Gen 1 interface. Samsung also offers its free Magician software, which has long been the gold-standard SSD suite for monitoring and performing maintenance on your drives.

So to speed. In CrystalDiskMark, it scored 442MB/sec sequential reads and 395MB/sec writes. Compare that

ABOVE The robust design provides a measure of protection

ABOVE The T5 Evo ships with a 40cm long USB-C to USB-C cable

to the Samsung T9 Portable SSD (*see issue 351, p59*), which returned speeds closer to 2,000MB/sec. That has a peak capacity of 4TB and costs £365, so £55 more than the T5 Evo. For the record, the last portable hard drive we tested – the WD Passport (*see issue 324, p91*)– delivered around 110MB/sec in our sequential read/write tests.

Who should buy the T5 Evo, then? Its 8TB top-end capacity may well find niche appeal among videographers who need lots of solid-state space on the go. And its semi-rugged design gives extra reassurance that it will survive a few bashes. However, Samsung is asking a huge premium for this device, so my advice is to look out for discounts – something that often happens with Samsung's portable drives. **MATT SAFFORD**

SPECIFICATIONS
2TB/4TB/8TB external SSD ● USB-C 3.2 Gen 1 interface ● up to 460MB/sec sequential read/write ● AES 256-bit hardware encryption ● 40 x 17 x 95mm (WDH) ● 102g ● 3yr limited warranty

PRINTERS
THAT LAST

Don't buy throwaway printers that end up in landfill after a year and cost a fortune to run. We review 14 contenders that make long-term sense

CONTENTS

At the time of writing, you can buy an HP DeskJet 2710e all-in-one colour printer for £27.50. It includes six months of ink subscriptions (HP calls this Instant Ink), looks perfectly attractive and its output is, well, acceptable for the price. But we don't think you should buy it, and we didn't include it in this test.

You may wonder why. An antipathy towards HP, perhaps? Well, no: we could have easily selected similarly priced machines from Canon and Epson as our example. Or perhaps *PC Pro* is on a quest to make our readers buy expensive printers? Again, no. We love a bargain as much as the next world's-best technology magazine.

The reason we don't include such printers is that they're designed to hook buyers with a cheap price and then either lure them with subscriptions (*see View from the Labs, p95*) or enforce costly cartridge purchases. For example, HP's XL cartridges cost £19 for colour and £21 for black, so each time you replace the cartridges – and you'll need to do so frequently, as they only last for up to 240 pages – that's £40 down the drain. Money that could have gone towards a printer that produced higher-quality prints more quickly. And that produced better scans. And photocopies.

That's why we focus on "printers that last" in this Labs. And also why we were so keen to review as many refillable options as possible. With six lasers alongside eight inkjets, we hope one fulfils your needs for 2024 – and long beyond.
CONTRIBUTOR: Simon Handby

	Brother DCP-J1800DW	Canon Maxify GX2050	Canon Maxify GX5550	RECOMMENDED Canon Pixma TS8750	LABS WINNER – INKJETS Epson EcoTank ET-2830	Epson EcoTank ET-14100	Epson EcoTank ET-18100
Print technology	COLOUR INKJET	COLOUR INKJET	COLOUR INKJET	COLOUR INKJET	PIEZO COLOUR INKJET	PIEZO COLOUR INKJET	PIEZO COLOUR INKJET
Overall rating	★★★☆☆	★★★☆☆	★★★★☆	★★★★☆	★★★★★	★★★☆☆	★★★★☆

Information

Price (inc VAT)	£133 (£160)	£301 (£361)	£383 (£459)	£132 (£159)	£208 (£250)	£497 (£596)	£525 (£630)
Supplier	viking-direct.co.uk	printerbase.co.uk	printerbase.co.uk	printerbase.co.uk	epson.co.uk	ballicom.co.uk	printerbase.co.uk
Manufacturer	brother.co.uk	canon.co.uk	canon.co.uk	canon.co.uk	epson.co.uk	epson.co.uk	epson.co.uk
Warranty	1yr RTB	3yr on-site exchange (with registration)	3yr on-site exchange (with registration)	1yr RTB	1yr/50,000 pages RTB	1yr/50,000 pages RTB	1yr/50,000 pages RTB
Dimensions (WDH)	400 x 341 x 172mm	374 x 380 x 225mm	399 x 410 x 298mm	372 x 345 x 142mm	375 x 347 x 179mm	498 x 358 x 165mm	523 x 369 x 150mm
Weight	8.3kg	8.1kg	10.4kg	6.6kg	4.1kg	6.4kg	8.0kg

Printing

Max print resolution	1,200 x 6,000dpi	600 x 1,200dpi	600 x 1,200dpi	4,800 x 1,200dpi	4,800 x 1,200dpi	4,800 x 1,200dpi	5,760 x 1,440dpi
Mono speed (claimed/tested)	17ppm/15ppm	15ppm/13.4ppm	24ppm/19.7ppm	15ppm/13.4ppm	15ppm/12.3ppm	15ppm/14ppm	22ppm/7.9ppm
Colour speed (claimed/tested)	17ppm/6ppm	10ppm/4.8ppm	15.5ppm/4.9ppm	10ppm/3.9ppm	8ppm/4.5ppm	8ppm/4.5ppm	22ppm/5.3ppm
Paper input (capacity)	Cassette (150)	Cassette (250)	Two cassettes (250 + 250), rear tray (100)	Cassette (100), rear tray (100), printable optical disc tray	Rear tray (100)	Rear tray (100)	Rear tray (80)
Paper output	50	Not stated	Not stated	Not stated	30	100	100
Paper maximum size (weight)	A4/legal (300gsm)	A4/legal (265gsm)	A4/legal (265gsm)	A4/legal (300gsm), custom length to 676mm	A4/legal (300gsm)	A3+ (300gsm)	A3+ (300gsm)
Double-sided printing	✓	✓	✓	✓	✗	✗	✗
Black cartridge (pages)	LC421XLBK (500 pages)	GI-55BK (3,000 pages)	GI-56BK (6,000 pages)	PGI-530PGBK (400 pages)	104 black ink (4,500 pages)	104 black ink (4,500 pages)	107 black ink (3,600 pages)
Colour cartridge (pages)	LC421XLC cyan, LC421XLM magenta, LC421XLY yellow (500 pages each)	GI-55C cyan, GI-55M magenta, GI-55Y yellow inks (3,000 pages each)	GI-56C cyan, GI-56M magenta, GI-56Y yellow inks (14,000 pages each)	CLI-531C cyan (515 pages), CLI-531M magenta (475 pages), CLI-531Y yellow (515 pages), CLI-531BK black (not stated), CLI-531GY grey (not stated)	104 cyan, magenta, yellow inks (7,500 pages each)	104 cyan, magenta, yellow inks (7,500 pages each)	107 cyan, light cyan, magenta, light magenta, yellow inks (7,200 pages each)
Cost per page mono (standard)	2.8p (ISO/IEC 24711)	0.26p (ISO/IEC 24711)	0.17p (ISO/IEC 24711)	3.5p (ISO/IEC 24711)	0.15p (ISO/IEC 24711)	0.15p (ISO/IEC 24711)	0.19p (ISO/IEC 24711)
Cost per page colour (standard)	6.5p (ISO/IEC 24711)	0.78p (ISO/IEC 24711)	0.36p (ISO/IEC 24711)	6.4p (ISO/IEC 24711)	0.25p (ISO/IEC 24711)	0.25p (ISO/IEC 24711)	0.49p (ISO/IEC 24711)
Monthly duty cycle (pages)	Not stated	27,000 (max)	45,000 (max)	Not stated	Not stated	Not stated	Not stated

Other functions

Max scan resolution	1,200 x 2,400dpi	1,200 x 2,400dpi	N/A	2,400 x 4,800dpi	1,200 x 2,400dpi	N/A	N/A
Automatic document feeder	20 sheets	35 sheets	✗	✗	✗	✗	✗
Fax	✗	✓	✗	✗	✗	✗	✗
Mobile/cloud features	AirPrint, Android, Brother Web Connect, iOS, Mopria	AirPrint, Android, iOS, Mopria, Pixma Cloud Link	AirPrint, Android, iOS, Mopria, Pixma Cloud Link	AirPrint, Android, iOS, Mopria, Pixma Cloud Link	AirPrint, Android, Epson Connect, iOS	AirPrint, Android, Epson Connect, iOS	AirPrint, Android, Epson Connect, iOS

Interface

Display	6.8cm colour touchscreen	6.7cm colour touchscreen	6.7cm colour touchscreen	10.8cm colour touchscreen	None	None	None
Front connections	None	None	None	SD card slot	None	None	None
Rear panel	USB, 10/100 Ethernet	USB, 10/100 Ethernet	USB, 10/100 Ethernet	USB	USB	USB	USB
Wireless	802.11b/g/n	802.11b/g/n/a/ac	802.11b/g/n/a/ac	802.11b/g/n/a/ac	802.11b/g/n	802.11b/g/n	802.11b/g/n

Power (measured)

Sleep (W)	0	0	0	0	0	0	0
Standby (W)	2	4	3	5	3	3	2
Active (printing or copying, W)	16	24	20	25	15	13	17

	RECOMMENDED	LABS WINNER – LASERS					
	HP OfficeJet Pro 9012e	**Brother HL-L9430CDN**	**HP LaserJet Pro MFP 4302fdw**	**HP LaserJet Enterprise 5700dn**	**Kyocera Ecosys P2235dn**	**Lexmark B3340DW**	**Xerox C230DN**
	COLOUR INKJET	COLOUR LASER	COLOUR LASER	COLOUR LASER	MONO LASER	MONO LASER	COLOUR LASER
	★★★★☆	★★★★★	★★★☆☆	★★★☆☆	★★★☆☆	★★★☆☆	★★☆☆☆
	£173 (208)	£415 (£498)	£341 (£409)	£612 (£735)	£165 (£199)	£146 (£175)	£221 (£265)
	printerland.co.uk	printerland.co.uk	printerland.co.uk	printerland.co.uk	printerbase.co.uk	printerbase.co.uk	printerbase.co.uk
	hp.co.uk	brother.co.uk	hp.co.uk	hp.co.uk	kyoceradocumentsolutions.co.uk	lexmark.co.uk	xerox.co.uk
	Up to 3yr with HP+ activation and registration	1yr RTB	1yr, next business day on-site	1yr, next business day on-site	1yr RTB (drum, 3yr/100,000 pages)	3yr RTB (with registration)	2yr RTB (with registration). Up to 5yr with qualifying toner purchases
	439 x 343 x 278mm	442 x 541 x 403mm	421 x 435 x 384mm	500 x 460 x 415mm	375 x 393 x 272mm	368 x 363 x 222mm	411 x 394 x 244mm
	9.3kg	29.0kg	20.4kg	31.1kg	14.0kg	9.3kg	16.1kg
	4,800 x 1,200dpi	2,400 x 600dpi	600 x 600dpi	1,200 x 1,200dpi	1,200 x 1,200dpi	2,400 x 600dpi	600 x 600dpi
	22ppm/21.1ppm	44ppm/30.6ppm	33ppm/25ppm	43ppm/30ppm	35ppm/28.8ppm	38ppm/30.6ppm	22ppm/10.5ppm
	18ppm/6.9ppm	44ppm/21.8ppm	33ppm/14.4ppm	43ppm/14.6ppm	N/A	N/A	22ppm/6.6ppm
	Cassette (250)	Cassette (520), multipurpose tray (100)	Cassette (250), multipurpose tray (50)	Cassette (550), multipurpose tray (100)	Cassette (250), multipurpose tray (100)	Cassette (250), multipurpose tray (100)	Cassette (250), manual feed (1)
	60	250	150	250	250	150	150
	A4/legal (300gsm)	A4/legal (230gsm)	A4/legal (200gsm)	A4/legal (220gsm)	A4/legal (220gsm)	A4/legal (217gsm)	A4/legal (176gsm)
	✓	✓	✓	✓	✓	✓	✓
	967XL (3,000 pages)	TN821XXL BK (15,000 pages)	220X BK (7,500 pages)	213Y BK (18,000 pages)	TK-1150 (3,000 pages)	B342X00 extra-high yield (6,000 pages)	006R04391 (3,000 pages)
	963XL cyan, magenta, yellow inks (1,600 pages each)	TN821XXL C cyan, TN821XXL M magenta, TN821XXL Y yellow (15,000 pages each)	220X C cyan, 220X M magenta, 220X Y yellow (5,500 pages each)	213Y cyan, 213Y magenta, 213Y yellow, (12,000 pages each)	N/A	N/A	006R04392 cyan, 006R04393 magenta, 006R04394 yellow (2,500 pages each)
	1.0p (ISO/IEC 24711)	0.9p (ISO/IEC 19798)	1.5p (ISO/IEC 19798)	1.2p (ISO/IEC 19798)	1.8p (ISO/IEC 19798)	2.0p (ISO/IEC 19798)	2.6p (ISO/IEC 19798)
	4.2p (ISO/IEC 24711)	6.1p (ISO/IEC 19798)	8.0p (ISO/IEC 19798)	6.5p (ISO/IEC 19798)	N/A	N/A	10.1p (ISO/IEC 19798)
	1,500 (recommended), 25,000 (max)	12,000 (recommended)	4,000 (recommended), 50,000 (max)	2,000-10,000 (recommended), 80,000 (max)	20,000 (max)	500-5,000 (recommended), 50,000 (max)	30,000 (max)
	1,200 x 1,200dpi	N/A	1,200 x 1,200dpi	N/A	N/A	N/A	N/A
	35 sheets	✘	50 sheets	✘	✘	✘	✘
	✓	✘	✓	✘	✘	✘	✘
	AirPrint, Android, iOS, Mopria	AirPrint, Android, Brother Web Connect, iOS, Mopria	AirPrint, Android, HP Smart, iOS, Mopria	AirPrint, Android, HP Smart, iOS, Mopria	Android, iOS	AirPrint, Mopria	AirPrint, Chromebook printing, Mopria
	6.9cm colour touchscreen	8.8cm colour touchscreen	10.9cm colour touchscreen	10.9cm colour touchscreen	None	Two-line mono backlit	Two-line mono backlit
	USB	USB, NFC	USB	USB	USB	None	None
	USB, 10/100 Ethernet	USB, gigabit Ethernet	USB, gigabit Ethernet	USB, gigabit Ethernet	USB, gigabit Ethernet	USB, 10/100 Ethernet	USB, 10/100 Ethernet
	802.11b/g/n/a	No (optional)	802.11b/g/n/a/ac	No (optional)	No (available on P2235dw)	802.11b/g/n	802.11b/g/n
	0	0	1	0	0	0	0
	6	11	13	27	6	5	14
	23	1,054	1,130	660	962	770	464

Choose a printer that meets your long-term needs

Want the right printer for your home or office? Our buying guide explains what to look for right now and in years to come

Nobody buys a printer or multifunction peripheral thinking it's going to change their life, but pick the right one and it will certainly make things better. And if you pick the wrong one... let's just say that it makes sense to cut your losses sooner rather than later.

That's why it's worth putting in the legwork now. Research, research, research, to paraphrase a former Prime Minister. But with such a huge range of options for almost any size of budget, how do you know what's right for you?

STEP 1 Key features

Start by looking at what you'll use it for. In many cases, buying a multifunction peripheral (MFP) costs little more than a standard printer, and adds the ability to scan and make copies. And if you're doing business internationally or in some more conservative industries, you might find you still need to send or receive faxes.

If you're mostly looking for something to handle the occasional print or maybe scan the kids' homework, a more basic MFP probably fits the bill. But if you're buying for a company, look for business features such as an automatic document feeder (ADF). So equipped, an MFP can make multi-page copies or send long faxes without you needing to lift a finger.

Talking of which, we tend to recommend devices that are duplex-capable – in other words, they'll print

ABOVE Features such as duplex printing can be very useful in a busy office

With an automatic document feeder, an MFP can make multi-page copies or send long faxes without you needing to lift a finger

or scan both sides of a sheet without you needing to flip it over. Duplex printing saves on paper, and it makes for professional-looking documents and presentations. Get an MFP with a duplexing scanner and printer, and it can print, scan, copy or fax two-sided documents while you put your feet up.

STEP 2 Paper handling

It pays to consider any other needs you might have for paper handling. For example, if you'll often print photos, you might want an inkjet with a second tray for glossy paper. If your business prints on headed paper, look for a device with two cassettes or a generous second paper feed. And if you'll regularly do long print runs, check the output tray holds enough pages that you won't be constantly emptying it.

LEFT HP's OfficeJet Pro 9012e allows you to send and receive faxes as well as print and scan

The final thing to consider is whether you want to buy additional paper input trays. A busy office can whistle its way through 500 pages with ease, so adding a second tray means less time spent refilling and avoids the hassle of a job stopping halfway through.

STEP 3 Inkjet or laser?

It's no accident that the inkjet/laser discussion doesn't come first in our buying guide – inkjets have improved to the point that they're a genuine alternative for many business applications, and certainly for a home office. It's still true that lasers tend to be faster and more robust, so they're a great choice if you'll be printing in higher volumes. That said, they can be expensive to run, and some of them have as many as 11 consumables to worry about.

Inkjets usually have four to six cartridges, and sometimes a replaceable maintenance box. You can choose between office-orientated devices, all-rounders and photo-focused models. The latter tend to be slower and don't usually have an ADF, but they'll usually turn out better photo prints and may also be better for scanning photos.

ABOVE Canon's Maxify inkjets are extremely economical when it comes to running costs

STEP 4 Running costs

Inkjets can be expensive to run, but with a choice of refillable ink tanks and ink subscription plans, the cheapest have far lower running costs than their laser equivalents (*see View from the Labs, p95*).

However, this is one area where it pays to dig into the detail. Work out roughly how many printouts you already do per month, and whether that's likely to change, and do some number crunching (bearing in mind that manufacturers tend to be optimistic about how many prints you can get per cartridge). You may be surprised by the results.

STEP 5 Ports and Wi-Fi

Every printer has a USB connection, and these days almost every printer also offers wired or wireless networking (sometimes both). Modern wireless networks are more than capable of handling the traffic to a printer, and even the large amounts of data sent by a scanner, but make sure that you have a strong Wi-Fi signal where you're planning to put your device. If not, reposition your router, or consider using a wired connection to a printer's Ethernet port.

We don't generally recommend printers without a network

How we test
We test every device for speed, quality and usability

We start by setting up every device, connecting it to the internet where supported, and downloading any firmware updates we're offered. We then download the full software package from the manufacturer's website, applying any updates, before performing alignment or nozzle checks if prompted.
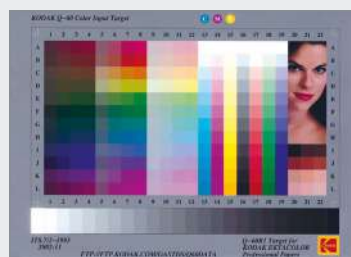
ABOVE We use a Kodak Q60 colour target to test a scanner's accuracy

Print tests

First, we print a set of documents designed to showcase text quality. This done, we break out the stopwatch and set about seeing how fast a printer can move. The first test is to time 25 identical pages of black text, recording the first-page-out time, and calculating the overall speed in pages per minute (ppm). On inkjets, we'll repeat this test in draft or economy mode, and on lasers we'll repeat it after an hour of idling to get a first-page-from-cold time. On office-focused devices we also print a 50-page text document, which gives faster printers a chance to really stretch their legs.

Next, it's time to look at graphics performance with a 24-page colour document comprising magazine pages, presentation slides and a set of ten web pages. It's a stern challenge, usually emerging far more slowly than the manufacturer's stated speed even on a mono printer. On printers that support automatic double-sided printing, we also duplex the first ten pages of this document to calculate a speed in images per minute (ipm). Finally, we measure how long it takes to get a first colour page out, again repeating this test

on laser printers once they've been idle for an hour.

Our final print tests look at photo speed and quality. On an inkjet we'll time six 10 x 15cm photos on glossy paper, without borders if available, and at the highest possible quality. On a laser we print three A4 pages containing the same images, again at the best quality available. We print two further A4 sheets containing 10 x 8in photos – again using the best quality settings, and coated paper on an inkjet. Finally, we time A4, A3 and A3+ borderless photos where possible, and print a sample black-and-white image.

Photocopy and scan tests

We're not finished yet with an MFP, on which we'll time single black and colour copies. If there's an ADF we'll also time ten copies, and if it supports duplex we'll time a 10-page, 20-side colour copy for good measure.

We'll then note how long it takes to preview an A4 page, and to scan it at 150 and 300 dots per inch (dpi). We also scan a 10 x 15cm photo at 600dpi and 1,200dpi (where available), finally using a Kodak Q60 colour target to test the scanner's colour accuracy and dynamic range. While we're working, we measure every printer's sleep, standby and peak power use, too.

You'll find the results of all our tests either in the feature table on p80 or the performance graphs on p94. And where a printer is particularly quick, slow, good or bad, we'll always talk about it in our review.

connection. They're much harder to share, and they miss out on cloud features, such as being able to print from, or scan to, your Google Drive or Dropbox storage.

STEP 6 Direct printing

If you're keen on photography, consider a printer with a memory card slot for direct prints. In an office, a USB host port is more likely to be useful – it lets you print from, or scan to, a thumb drive.

This is also where the quality of the screen and the interface makes a difference, and we mention in the reviews if these are especially good (or annoying). If you know that you'll be

doing a lot of direct printing, opt for a larger, colour screen if budget allows.

STEP 7 A question of speed

We test every printer for speed, but in a home or home office it might not be that important a factor. A fast printer is wasted if you're just printing the occasional page or two, while a slow one is costing you time if several people are trying to print off letters, reports or other office documents. Generally speaking, laser printers offer the fastest text and graphics speeds, but they tend to need longer to start printing. That's especially true if they've been left idle, after which they may need a minute or so to warm up again, ready for use.

STEP 8 Think longevity

Finally, try to choose a printer that will last you for years. We print each manufacturer's results for reliability – based on the experience of our readers – in the feature table on p80, along with the warranties. For office-oriented printers, look closely at the monthly duty cycles as well.

LEFT A cut above: Brother's DCP-J1800DW can guillotine pages as they're being printed

Brother HL-L9430CDN

Fast, versatile and comparatively cheap to run, the HL-L9430CDN is this month's stand-out laser

SCORE ✪✪✪✪✪

PRICE £415 (£498 inc VAT)
from printerland.co.uk

I t's hard to get excited about a laser printer, but Brother's HL-L9430CDN might just put a hop in an office manager's step. It's a big beast, designed for use in small businesses and workgroups, and it comes with a suitable specification. In the base there's a fully enclosed 520-sheet paper cassette, while the large flap at the front hides a 50-sheet multipurpose feed. Printed pages emerge into a 250-sheet tray on the top.

So far, so standard, but the HL-L9430CDN offers direct control through a large 8.8cm colour touchscreen. While many business printers run rather cryptic, unfriendly menus, Brother's is simple, offering quick access to functions and settings. It's enhanced with web features, allowing you to access and print from cloud services such as Dropbox, Google Drive and SharePoint. Hidden nearby on the left panel there's a USB host port for walk-up printing.

The final front panel feature is an NFC reader, used to control access if you need to lock down users or features. Using the printer's web interface you can block people from printing, using the USB port or accessing web functions, or you can limit the number of pages an individual can print.

It comes with USB and gigabit Ethernet ports. Curiously you can't buy it off the shelf with a wireless interface, but Brother will sell you one as an option. There's also a rear USB port for secure printing. Brother offers a range of extra paper trays and a staple finisher, so this printer can grow to match your business' needs.

Load it up and you'll see the usual nag about setting the correct paper type. The HL-L9430CDN follows this by asking if you ever want to see the question again – a brilliant timesaver if, like us, you rarely change paper type and it simply gets on your nerves. We were also happy to see clear

orientation marks at the front of the main tray and in the centre of the multipurpose feed. Too many lasers force you to unload the paper just to see how to orientate the stack; a pain if you're re-using previously printed pages, or using single-sided media.

Start printing and it's clear that this is a very rapid device. However, if it's been idle for any length of time the warm-up period can be toe-tappingly long. After an hour of rest we timed a first black text page out in 25 seconds, but the first colour page of the day took nearly a minute and a half.

This pause aside, the HL-L9430CDN made mincemeat of our tests. It reached 30.6ppm when printing 25 text pages, and managed 34.9ppm on our 50-page document. Both fall a way short of the stated 44ppm engine speed, but our tests include the time taken to spool and send the job. Discount this and it was almost bang on target.

Like all printers, the HL-L9430CDN was slower when printing our challenging colour graphics test. Here it reached 21.8ppm, the fastest colour result in this test, and not far behind the 27.7ppm mono result recorded by Kyocera's P2235dn. At the best Fine print quality it delivered

ABOVE The big and fast HL-L9430CDN has good paper-handling features

PC PRO LABS WINNER
LASER PRINTER

BELOW The printer comes with generous amounts of toner

two 10 x 8in photos on A4 paper in only 22 seconds, and six 10 x 15cm prints on three A4 sheets in 21 seconds. It duplexed ten sides onto five sheets at a rate of 14ipm.

So often, a promising colour laser is torpedoed by high running costs, but happily that's not the case here. The HL-L9430CDN is complex, requiring four toners, a drum, a waste bottle and transfer belt, but even factoring in all these it costs 0.9p per black page or 6.1p in colour. This printer arrives with generous 9,000-page black and 6,500-page colour inbox toners. With the largest replacements good for 12,000 black or 9,000 colour pages, maintenance intervals shouldn't be too frequent.

While not offering perfect colour reproduction, the HL-L9430CDN still made a good job of our test photos, and printed excellent colour graphics with a pleasing lustre. Black text was as good as you'd expect, too. Overall we could hardly call this hulking laser exciting, but it delivers everything you need in a busy business printer. And with Brother having won our Best Printer Manufacturer award for ten years in a row (*see issue 351, p26*), you can expect great reliability and support, too.

INKJET PRINTER

Epson EcoTank ET-2830

Basic, but it produces great results – and it's about as cheap as refillable inkjet MFPs get

SCORE ★★★★★

PRICE £208 (£250 inc VAT) from epson.co.uk

If Epson's EcoTank ET-2830 was a normal inkjet we'd be bemoaning its high price and taking aim at a relatively basic specification. We'll come back to the latter, but the first is explained by this MFP's refillable ink tanks. The ET-2830 arrives with about 6,000 pages' worth of bottled ink – enough to see out a year or two of light use in the home. It's better value out of the box than a comparable entry-level, cartridge-based device.

And entry-level the ET-2830 is. It's a three-in-one, able to print, scan and copy, yet there's no display, no USB port and no memory card slot. Instead, you get a few buttons and LEDs, and a reasonably appealing and uncluttered design. It offers just a single rear paper feed, and a basic scanner with no ADF. The printer can't flip over pages for double-sided prints, although the driver will help you do it manually.

The ET-2830 arrives with blue tape holding down every conceivable flap. Remove that and it's time to flip open its ink tanks and empty the supplied black and colour inks into the relevant nozzle – they're physically keyed to prevent a disastrous misfuelling. This is usually the bit where we gripe about waiting for the one-off ink priming to complete, but Epson's new Smart Panel app lets you join the MFP to a wireless network and get on with installing software while you wait. We found its verbosity annoying, but it worked perfectly and turned out to be a time-saver overall.

Once set up, this MFP offers no real surprises. Despite its basic nature, it will happily get on with regular household or micro-office duties, leaving printed pages in a neat stack. As you might expect, it's not especially fast, managing only 12.3ppm on our 25-page black

text test. However, with the print quality dropped to draft it reached 17.2ppm – significantly more than Epson's stated 15ppm.

Cheaper inkjets often make a meal of our challenging 24-page colour graphics test, but the ET-2830 chugged along at a steady 4.5ppm – more competitive than it sounds. It wasn't even that slow when printing larger photos, needing about three minutes for each 10 x 8in shot printed onto A4 paper. Unfortunately, it only offers borderless prints on 10 x 15cm paper, on which it took a beard-lengthening 14 minutes to deliver six prints. Colour photocopies provided another opportunity to grow facial hair, with a single copy needing 35 seconds. At least mono copies, at 14 seconds each, were relatively brisk.

The ET-2850's scanner didn't hang about at lower resolutions. It completed a preview in 12 seconds, and in the same timeframe could capture an A4 document at 150dpi. At 300dpi, the same job took 22 seconds. Things got slower at middling resolutions, with the scanner needing

ABOVE A simple rear tray, no ADF, no display – the ET-2830 is thin on features

PC PRO LABS WINNER
INKET PRINTER

BELOW These ink tanks make all the difference, turning this MFP into a bargain

37 seconds to capture a 10 x 15cm photo at 600dpi. However, scan speeds remained competitive at 1,200dpi, with the same document needing just less than a minute.

Delightfully, there's nothing especially entry-level about the quality of this MFP's prints, scans or copies. Draft text was quite faint, but Normal quality produced crisp and dark results. Colour graphics weren't the boldest we've seen, but they were free of banding, and comfortably good enough for home and internal business use. Photocopies faithfully reproduced the originals – although colour copies were a touch less saturated.

This MFP's photo prints were a highlight of our tests, combining surprisingly crisp details with vivid colours and realistic skin tones. Only our black and white photo presented a challenge, with the ET-2830 adding a slight green tint and failing to preserve the darkest shade details. We were also very impressed with its scan quality, which combined excellent colour accuracy with a wide dynamic range, making the most of office documents and photographs.

The EcoTank ET-2830 may be basic, but it's not unduly slow, and it does everything well. Yes, it's missing duplex printing and other helpful features, but it's about as cheap as refillable inkjets get. Once you've used up the generous bundled ink, its ongoing running costs are less than 0.5p per colour page. Don't be fooled by the purchase price: the ET-2830 is a bargain.

JARGON BUSTER **Duplex** Double-sided printouts; automatic duplex means you don't need to turn over the pages yourself. **Duty cycle** The maximum number of pages that a printer is designed to cope with in a given amount of time, usually a month, without affecting wear and tear.

Canon Pixma TS8750

It's comparatively pricey, but the TS8750 is great for creative and general home printing

SCORE ★★★★☆
PRICE £132 (£159 inc VAT)
from printerbase.co.uk

While Canon's Maxify printers are aimed at home and small offices, the Pixma series is unapologetically focused on creative and home use. The Pixma TS8750 sits near the top of the current lineup; a six-ink MFP offering high-quality photo prints and detailed scanning. What it lacks in office features it makes up for with photo-friendly touches such as the memory card slot and a huge colour touchscreen display.

The TS8750 is a striking MFP, made from a mix of textured, shiny and translucent black plastics. Its squat stance makes it look as much like AV equipment as it does a printer. But although it looks as if you could sit the TS8750 on a bookshelf, you'd risk losing access to its scanner and its 100-sheet rear paper tray. The bulk of the MFP is inset slightly from a base that juts out at the front. Here you'll find a 100-sheet paper cassette and the card slot.

If it's not immediately obvious where paper comes out, all becomes clear when you start printing. The TS8750's motorised paper output tray emerges – tilting the front panel upwards – shortly followed by your first page. It's a slick party piece, partially reversed when you turn the MFP off; the panel itself isn't motorised, so it stays slightly open.

With manufacturers including Canon making a big push on refillable printers, it almost feels odd to fit the TS8750's six supplied cartridges. They're easy to insert and, although you can physically put them in the wrong slots, the printer won't initialise until it detects everything is ship-shape. This printer augments a standard black, cyan, magenta and yellow setup with grey and a second black cartridge. The three colours, grey and smaller black cartridges all contain dye-based inks, ideal for photo printing, while the main black tank is pigmented for strong black text on plain paper.

The TS8750's chunky SD card slot might seem to the smartphone generation like a relic, but it makes sense when many high-end cameras still use full-sized SD for storage. Insert a loaded card and the initial single-shot preview isn't that helpful. You can pull up a multi-frame view through which it's easier to find specific shots from a selection of snaps, but it won't let you batch select photos to print.

The TS8750 has two other foibles. There's a handy lip to help you pull out its main paper cassette, but it's obscured once the output tray is extended. The paper output tray has a flip-up stop, useful to rein in multiple pages after longer print jobs, but it's not extended automatically when the tray itself emerges.

We hit the TS8750 with our usual mix of office documents and photos. It wasn't especially fast, reaching just 13.4ppm over 25 pages of text, and only 3.9ppm on our demanding graphics test. Photo prints were snappier, with borderless 10 x 15cm postcards arriving every 70 seconds or so, although a borderless A4 print inched out over five minutes.

This is a reasonably fast scanner, completing a preview in 12 seconds, and needing 20 seconds to capture an A4 document at 150dpi. At a

ABOVE Squat, smart and very black, the TS8750 doesn't look like the average MFP

PC PRO RECOMMENDED

BELOW The huge 10.8cm touchscreen is a doddle to use

detailed 1,200dpi it needed 78 seconds to complete a 10 x 15cm photo scan. Copy speeds were middling, with a single page taking 17 seconds in black only or 23 in colour.

If we were underwhelmed by this MFP's speeds, it rose sharply in our estimations once we looked at our results. Black text was as crisp and bold as you'll get from an inkjet, while colour graphics were punchy and consistent, with only the merest hint of banding. Photocopies were very strong, with both mono and colour copies preserving the details of the original.

Without doubt, the best results came on glossy photo paper, and from the TS8750's scanner. Captured images showed a sharp focus with faithful colours and a wide dynamic range that preserved detail from the very lightest and darkest parts of originals. Photo prints were exceptional, offering perfectly reproduced skin tones, vibrant colours and crisp detailing. Unsurprisingly, given the dedicated black and grey inks, black and white prints were rich and free of any colour cast.

This isn't a cheap multifunction in the first place, and with a cost per page upwards of 10p, it won't prove especially economical in use. That's particularly true if you'll often print text, every page of which will set you back a steep 3.5p. However, if you want a smart home MFP that's as comfortable printing photos as it is scanning artwork, the TS8750 may well prove worth the premium.

JARGON BUSTER **ipm** Images per minute, a measure of speed that includes text, graphics and images, which we use to compare duplex printout speeds. **MFP** Multifunction peripheral, which will always include a scanner as well as a printer (so they can also photocopy); some MFPs also include a fax. **ppm** Pages per minute.

HP OfficeJet Pro 9012e

The OfficeJet Pro 9012e is a cracking home office MFP, producing great results in double-quick time

SCORE ★★★★☆
PRICE £173 (£208 inc VAT)
from printerland.com

HP's OfficeJet Pro 9012e is almost indistinguishable from the 9010e we crowned inkjet Labs winner this time last year. It's a chunky-looking, businessy MFP aimed squarely at home and small offices. While it's clearly not an enterprise-class device, it's built to take moderately high use, with a one-time maximum monthly duty cycle of up to 25,000 pages.

In reality this MFP is unlikely to print anywhere near that volume, but it's well set up for its recommended 1,500 pages a month. In its base you'll find a 250-sheet paper cassette, while on top there's a 35-sheet ADF. It can print, scan, copy and fax, with direct control coming via a 6.9cm colour touchscreen running a user-friendly menu. It's hidden slightly on the left side, but you also get a USB host port for direct prints and scans.

The "e" on some HP printers denotes that you must sign up to HP+ to activate the device, and thereafter leave it connected to the internet for it to function. Happily, that's not the case here, with users allowed to choose whether to activate HP+, the Instant Ink subscription service, or neither. We asked HP to clarify whether it had changed its "dual SKU strategy" which obliged users to choose HP+ or not at the time of purchase, but didn't hear back before we went to press.

Regardless, the 9012e offers the best of all worlds. Choose to sign up to HP+ and you'll get an additional year's warranty and six months of Instant Ink for free. Opt out and you can still get two years' cover with online registration, and choose to sign up to Instant Ink if you want. We discuss the economics of this in View from the Labs (see p95), but without it – at 1p per page in black or 4.2p in colour – the 9012e is cheap to run for a cartridge-based inkjet.

HP claims the 9012e has self-healing Wi-Fi, but we had issues connecting it to our regular Labs router – an unremarkable dual-band TP-Link. It couldn't detect the 2.4GHz network until we rebooted it, after which the printer failed to connect and lost sight of it again. We tried the 5GHz network with similar results, eventually giving up and using our main router. Although this worked without any problems, it's further away from the test area, which may have slowed the 9012e down.

If it did, we can't say we especially noticed. The OfficeJet Pro 9012e took quite a while to spool and start printing multi-page jobs, but once started it was the fastest inkjet in this group. It hit 21.1 pages per minute (ppm) on our 25-page text test, and reached an equally impressive 6.9ppm over 24 pages of colour graphics. Encouraged by these results we tried our 50-page *Alice in Wonderland* test, but with a very long spool time this proved slower at just 11.6ppm. The 9012e was also underwhelming when duplexing, reaching only 3.4ipm when printing ten sides of colour graphics.

For an inkjet, this is a fast copier, managing single black pages in nine seconds, and needing only ten

PC PRO
RECOMMENDED

seconds in colour. It rattled off ten mono copies in 71 seconds, and again needed little longer in colour, taking 79 seconds. A 10-page, 20-side duplex colour photocopy took nearly five minutes, however.

When it came to scanning, this was again the fastest inkjet here, despatching low-resolution A4 scans in only ten seconds. We were even more impressed at higher resolutions, the 9012e needing only 12 seconds to capture a 10 x 15cm photo at 600dpi.

The 9012e isn't a great photo printer, with its pigment inks drying to a dull, semi-matte finish. We were also disappointed in its slightly dark and dingy photocopies. Otherwise, it's hard to fault the quality of its prints and scans, particularly on typical office jobs such as text and colour graphics. It's certainly good enough for printing formal correspondence, and it would be great for archiving documents – if only it came with software that could save scans as searchable PDFs.

Overall, this remains a great MFP for a typical home office. It's fast, robust, produces good results, and is almost as cheap to run as cartridge-based inkjets get. However, its purchase price has crept up somewhat compared to the 9010e, so it loses out on value for money.

Multipurpose feed A tray that allows different sizes and types of paper/media to be fed in, as opposed to standard A3 or A4 paper in the main tray(s). **Platen** The scanning surface of a scanner. **TWAIN** Technology without an interesting name (yes, really). It's a protocol that helps apps control scanners.

Brother DCP-J1800DW

It has a unique paper-cutting party trick, but it's otherwise not a great MFP

SCORE ★★★☆☆

PRICE £133 (£160 inc VAT)
from viking-direct.co.uk

I f you've ever wished your printer could guillotine paper for you, the DCP-J1800DW might be a revelation. From the outside it's a typically squat Brother inkjet MFP, but inside there's a cutting blade, capable of carving each innocent A4 page into two A5 sheets. It may be niche, but it's brilliantly executed and apparently safe – we couldn't even spot where the blade is hidden, let alone reach it.

Slasher tendencies aside, this is an ordinary three-in-one MFP aimed at home office use. Despite the 20-page ADF on top, it doesn't support faxing, but it's reasonably well kitted out. It will turn out automatic double-sided (duplex) prints, and you can share it via a wired or wireless network. Everything is controlled via a clear 6.8cm colour touchscreen with a friendly menu system.

This MFP may be novel, but its cutting system is so well designed it feels like it's been around forever. It can print normally to the usual range of paper sizes, or you can choose to cut A4 pages down to size in two ways. "No resize" cuts an existing A4 page image into two – useful if you've designed a flyer or you're printing slides two to a page – while "Fit to cut page" will resize your document to A5. The system fully supports

duplexing, so you can, for example, print a multi-page document as a double-sided A5 booklet, saving plenty of ink and paper. It also works with photos, producing remarkably neat edges, but you can't combine cuts with borderless printing.

It's a shame, then, that the DCP-J1800DW isn't more remarkable elsewhere. It's fairly swift, delivering black text at 15 pages per minute (ppm), and colour graphics at a respectable 6ppm. It's also no slouch when it comes to scanning, capturing an A4 document at 150 dots per inch (dpi) in only ten seconds, and needing a mere 24 seconds to capture a 10 x 15cm photo at 600dpi. But on plain paper prints lacked impact, while its scans were too dark, leading to the loss of some shade detail.

With moderately high running costs, particularly in black, the DCP-J1800DW isn't ideal for larger print volumes. It could be perfect for those who need its cutting feature, but as an all-round MFP it falls short.

ABOVE This cutting-edge device looks like any other Brother inkjet MFP

BELOW They're big cartridges, but costs per page aren't especially low

Canon Maxify GX2050

The GX2050 isn't bad if low running costs are a priority, but it falls short of brilliance

SCORE ★★★☆☆

PRICE £301 (£361 inc VAT)
from printerbase.co.uk

C anon's Maxify GX2050 is an inkjet multifunction with refillable ink tanks. While that's no longer a novelty, it's worth reiterating the ink tank truism that you pay more up front, then save in the long term through much lower ink pricing. There are other benefits, too: chiefly that the GX2050 can go for several thousand pages between top-ups – that's a big time and hassle saving over a comparable cartridge-based inkjet.

The GX2050 can print, scan, copy and fax. It's equipped with a duplex printer, but its 35-sheet ADF is single-sided only – a shame if you want to make double-sided scans,

faxes or copies. You can connect and share it via wired or wireless networking, and control the MFP's direct functions using its tilting control panel. At 6.7cm the touchscreen is big enough, and enhanced by a few dedicated buttons, but the whole thing has an irritating tendency to fold backwards on its hinge when tapped. There's also no USB host port, which feels like a missed opportunity.

This is far from a slow MFP, but its performance might be too casual for busy small

RIGHT The 6.7cm screen is great but for its habit of folding back when tapped

ABOVE It's a squat MFP, but hardly the best looking

offices. Its 13-second first-page-out time is brisk, but it reached only a moderate 13.4ppm over 25 sheets of black text. Conversely, we were quite impressed with its 4.8ppm performance on our challenging colour graphics document. We've also no complaints about scan speeds, particularly for the sort of low- and medium-resolution document scanning common in an office.

We couldn't fault the GX2050 for its scan quality; it's about the best you'll get from an office-focused device. Photocopies were also excellent. Black text prints were superb, but plain paper graphics suffered from slight banding, most notably in areas of solid colour fills. With no borderless printing and pigmented inks the GX2050 isn't really set up for photo printing, but it will do a fair job if you insist.

Ultimately, this MFP's main attractions are the generous ink in its box and low ongoing running costs of around 1p per full colour page. Backed up by a three-year warranty (with registration), it should prove much cheaper to own than an equivalent cartridge-based printer – particularly if you'll print only in moderate volumes.

INKJET PRINTER

Canon Maxify GX5550

Laser-like for print quality, and it's streets ahead when it comes to running costs

SCORE ★★★★☆

PRICE £383 (£459 inc VAT)
from printerbase.co.uk

Canon's Maxify GX5550 is a single-function refillable inkjet printer with a mission to combine laser-like performance with laser-beating running costs. It's well specified, with two 250-sheet cassettes and a 100-page multipurpose feed, along with automatic duplex printing. Rummage around the back of the printer and you'll find a USB and Ethernet port, although you can also connect it to a wireless network.

This printer uses a near-identical control panel to the Maxify GX2050, combining a 6.7cm colour touchscreen with supplemental function buttons. It's a decent system, made all the better here by a stiffer hinge that doesn't slip backwards when you tap the screen.

The GX5550 is bundled with a full set of Canon's GI-56 series ink bottles. Replacement sets are rated for a huge 6,000 black and 14,000 colour pages. Canon says you can eke this out to 9,000 and 21,000 pages respectively in Economy mode. That means you're likely to spend less time buying and installing supplies than you would with a comparable laser printer. And with running costs just over 0.5p per colour page, you'll save a fortune, too.

The laser-slaying storyline suffers a slight knock in practice, though. The GX5550 isn't a slowpoke, but its 19.7ppm performance won't have many lasers quaking. The same is true of its 4.9ppm on our taxing colour graphics document, or indeed any job you throw at it. Its lack of warm-up time keeps it competitive over short, infrequent prints, but on longer jobs a laser will outpace it.

Happily, there's not much in it when it comes to print quality. Yes, inkjet prints lack the lustre you get from the best lasers, but the GX5550 delivers crisp black text, assertive colour graphics, and excellent photos, particularly on matte-coated papers.

With a maximum 45,000-page monthly duty cycle, backed up by a three-year warranty (with registration), the GX5550 is likely to stick around long enough for you to make the most of its low running costs. If you're not set on a colour laser, it's a very compelling alternative.

PC PRO RECOMMENDED

ABOVE A smart refillable inkjet, the GX5550 is a genuine laser alternative

RIGHT Two cassettes, duplexing and a 100-sheet rear feed add paper-handling flexibility

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INKJET PRINTER

Epson EcoTank ET-14100

Epson's EcoTank ET-14100 is a capable A3+ printer, but we're not sure who it's for

SCORE ★★★☆☆

PRICE £497 (£596 inc VAT)
from ballicom.co.uk

Epson's ET-14100 slots in below the ET-18100 in the EcoTank range. It's a refillable, four-colour inkjet capable of printing up to A3+ media. We're used to high asking prices for refillable printers, but even so the ET-14100's price seems steep. At the time of writing, it was only £25 or so cheaper than the ET-18100, a similarly specified six-ink printer that's focused more sharply on photo printing.

It's hard to work out exactly who the ET-14100 is for. Epson says it's aimed at small and home offices, but it's thin on office-orientated features. There's no automatic duplexing, for example, and it uses dye-based inks rather than the pigmented ones.

The ET-14100 arrives with enough ink to print a claimed 6,400 black or 5,600 colour pages. Get through those and its ongoing running costs work out at less than 0.5p per colour page. Black text printing is cheap, too, working out at just over 0.1p per page.

Speed-wise, it hit 14ppm when delivering black text, rising to 16.8ppm in draft mode, but dropped to 4.5ppm on our more challenging colour graphics test. The ET-14100 went on to print five A3 sheets of text at a rate of 3.7ppm, and five graphics-rich A3 pages at 2.1ppm. That's not a bad performance across a range of typical office jobs.

This wasn't the fastest photo printer, though, taking nearly six minutes over a borderless A4 print, and nine minutes on a borderless A3 print.

ABOVE The ET-14100 is fairly compact for an A3+ printer

BELOW Refillable ink tanks give it ultra-low running costs

It's worth noting that it can't print without borders on A3+ media.

Despite its dye-based inks, the ET-14100 created good-quality plain paper prints, even if they lacked the impact you'd get from a laser or the strongest office inkjet. Its photo prints were generally good, with landscapes in particular benefiting from vivid colours and sharp contrast, although our test black-and-white photo suffered from a slight green tint.

The ET-14100 is a capable photo printer, but the ET-18100 is better and costs little more. And while it isn't bad at plain-paper printing, it could be better. That leaves it occupying a niche, best suited for people who want to print comparatively high volumes on A3 without breaking the bank.

Epson EcoTank ET-18100

Delivers the cheapest six-ink photos available, but it's certainly not an all-rounder

SCORE ★★★★☆
PRICE £525 (£630 inc VAT)
from printerbase.co.uk

If you want to print lots of photos without breaking the bank, Epson's EcoTank ET-18100 printer will oblige. It's a six-ink A3+ photo printer with refillable ink tanks, giving it far lower running costs than its cartridge-based competitors. Otherwise, this single-function printer isn't particularly well specified. There's no memory card slot or display, for example, and no support for automatic duplex printing. On the plus side, the ET-18100 is remarkably compact for an A3+ printer with six ink tanks.

Epson's six-ink system combines the standard black, cyan, magenta and yellow inks with light cyan and light magenta. These allow this printer to create skin tones, blue skies and other mid and light shades using more dots of lighter colour, rather than fewer darker dots. In theory it's therefore harder to spot individual dots, helping reduce the appearance of grain in the finished print.

It works to an extent. The ET-18100 produced detailed, grain-free and high-quality prints across a range of subjects. However, it's not the best photo printer we've tested. We were particularly disappointed by a lack of subtle detailing in lighter skin tones, clouds and mid-light subjects such as sun-bleached wood – all of which should, in theory, benefit from this printer's extra two inks.

ABOVE The ET-18100 is compact for a six-ink A3+ printer

BELOW Refillable ink tanks help deliver very low print costs

Photos appeared fairly quickly, with the ET-18100 managing a borderless 10 x 15cm snap about every 80 seconds. It took less than three-and-a-half minutes over a borderless A4 print, and even produced a borderless A3+ portrait within six-and-a-half minutes.

The ET-18100 is far less accomplished on plain paper. It's a slow text printer, reaching only 7.9ppm on our 25-page test, but it proved more competitive with colour graphics, hitting 5.3ppm in this challenging test. There's little wrong with the quality of black text and graphics, but this printer's dye-based inks lack impact on plain paper, leading to a slightly washed-out appearance across the board.

Epson's yield figures suggest you'll pay about 0.7p per A4 page of text and colour graphics, or as little as 1.3p per 10 x 15cm photo. Even allowing for paper costs, that makes the ET-18100 far cheaper than commercial labs or other photo printers. If you'll print lots of photos, and you don't need the very best quality, it's a great choice.

HP LaserJet Pro MFP 4302fdw

The MFP 4302fdw promises much, but its colour prints and scans let it down

SCORE ★★★☆☆
PRICE £341 (£409 inc VAT)
from printerland.co.uk

HP's LaserJet Pro MFP 4302fdw looks like the perfect colour laser MFP for a small office. It's a four-in-one with fax, topped off by a 50-sheet ADF. Both this and the printer are duplex-capable, so you can start a multi-page double-sided copy and go off to put the kettle on.

This MFP has virtually no packing to remove – you can just load up paper, join it to a network and install the drivers. Unfortunately, that didn't go as smoothly as it should have. The touchscreen didn't confirm whether the 4302fdw had joined our Labs network, and it didn't respond when we repeatedly tried to print a network report. Shortly afterwards the printer sprang into life, delivering several unwanted copies.

We still don't love HP's TWAIN scan software, which in this case doesn't offer 150dpi, but its MFPs' lipless scan platens make it so much easier to retrieve your originals. This is quite a fast

RIGHT The 4302fdw's control panel makes life easy, but it wasn't always particularly responsive

ABOVE The blue front panel gives the printer a distinctive look

scanner, managing a 10 x 15cm photo at 600dpi in just 17 seconds, but it repeatedly dropped out midway through our 1,200dpi test.

If it's been idle for a while, the 4302fdw needs only about three seconds extra to warm up before delivering a first black or colour page. From standby it managed this in 17 seconds, and went on to deliver our 25-page test in exactly a minute. It was slower on our challenging colour test, but its 14.4ppm still compares well at this price.

At 1.5p in black or 8p per colour page this isn't the cheapest laser to run, but you can sign it up to HP's Instant Ink toner delivery, which brings the cost down as low as 1.3p. Unfortunately, you can't do much about the 4302fdw's indifferent print and scan quality. Black text was perfect, but graphics and photographs had a blue bias, apart from skin tones, which tended to look flushed. Office scans were perfectly good, but with photos we noticed a loss of detail from the darkest areas.

It's a shame. The LaserJet Pro MFP 4302fdw should be the perfect small office device, but its results are just a little too weak.

HP LaserJet Enterprise 5700dn

It's big, fast and even quite smart, but HP's 5700dn is slow to print in colour

SCORE ★★★★☆

PRICE £612 (£735 inc VAT)
from printerland.co.uk

HP's LaserJet Enterprise 5700dn ought to have walked this group test. As the name suggests, it's a large, enterprise-ready colour laser, full of power features such as HP Wolf Security, cloud-connected HP Workpath apps, and compatibility with HP's Open Extensibility Platform. In the base it has a 550-sheet paper tray, while on top there's a 250-sheet output bin. It's built to work, with an 80,000-page one-time monthly maximum, and a recommended duty cycle of up to 10,000 sheets a month.

The 5700dn is arranged sideways, with paper loaded and ejected with a landscape orientation relative to the user. That means its 100-sheet multipurpose feed is at the side, placing limits on where you can position it. You can choose from nine colours for the front panel, behind which lurk four combined toner and drum cartridges, but we love the standard Atmosphere Blue. Next to Brother's HL-L9430CDN, it's a good-looking printer.

Looks aren't everything, however, and the 5700dn was

ABOVE HP's LaserJet Enterprise 5700dn is quiet and good looking

RIGHT As expected on an enterprise printer, the LCD panel is large and easy to navigate

disappointing in some of our tests. We can't complain about its 17-second first-page-out time, or the 30ppm it managed on our 25-page text test. And we were deeply impressed by its 30.8ipm performance when duplexing our 50-page text document.

However, things were less speedy in colour, where the 5700dn struggled to reach just 14.6ppm on our graphics test and 8.2ipm in duplex. In part, the figures are explained by longer spool times for graphics jobs, but all our photo and graphics test speeds were disappointing for this class of device.

The 5700dn makes amends with excellent print quality, particularly its unbeatable black text and rich colour graphics. Only photo prints disappointed, with skin tones and other subtle colour progressions tending towards blockiness. Also note that, despite its size and speed, this is a surprisingly quiet laser.

The 5700dn's buyers are likely to favour managed print contracts, but buy consumables yourself and running costs are reasonable – 1.2p per black page and 6.5p in colour. Overall it's a good choice, particularly as you can apply for a free three-year warranty extension until April 2024, but we'd choose the HL-L9430CDN.

Kyocera's EcoSys P2235dn

A fast mono laser printer, but print quality and running costs could be better

SCORE ★★★☆☆

PRICE £165 (£199 inc VAT)
from printerbase.co.uk

Kyocera's EcoSys P2235dn is a compact mono laser printer, designed for moderate use in small groups or businesses. It's well specified for the price, with a 250-sheet cassette and 100-sheet multipurpose feed, plus duplex printing as standard. It's also equipped with a gigabit Ethernet port, but there's no Wi-Fi support; you'll need the P2235dw for that.

Most laser manufacturers regard photoconductor drums as a consumable, typically good for 10,000 to 40,000 pages, but Kyocera fits a ceramic drum designed to last the life of the printer; in this case, 100,000 pages. The drum is guaranteed to reach that, or to last for three years, but in the UK the printer itself gets a stingy one-year RTB warranty.

The P2235dn has a basic control panel comprising a few lights and buttons, so it's odd to see it also has a USB host port, which is typically paired with a text or touchscreen so you can browse and select which contents to print. We searched Kyocera's website

ABOVE Black, white, sensible: the P2235dn plays it straight

RIGHT Kyocera's ceramic drum is designed to last the life of the printer

and documentation, experimented with different files and button combinations, checked in the driver and combed through the web admin page, but simply couldn't find out how to make direct prints.

Using our trusty PC, we subjected the P2235dn to our usual battery of print jobs. It's a fast device, turning out a first page of text in 17 seconds, and continuing at 28.8ppm over our 25-page job. It extended this to 29.4ppm on a 50-page document, and even reached 12.5ipm when duplex printing ten sides of graphics onto five pages. We were particularly impressed by its 27.7ppm on our challenging 24-page graphics test.

Sadly, the P2235dn seems in too much of a hurry to print particularly well. It's rare that we criticise text quality from a laser, but up close, character outlines weren't as crisp as we'd expect. More significantly, mono graphics suffered from fine banding, something we'd usually only expect on the cheapest laser devices.

When considered with its 1.8p per page running costs, this lacklustre print quality takes the shine off the P2235dn. It's a good choice if speed is all important, but there's little else to recommend it.

Lexmark B3340DW

It's a fast text printer, but there's little else to recommend the B3340DW

SCORE ★★★☆☆
PRICE £146 (£175 inc VAT)
from printerbase.co.uk

Lexmark's B3340DW is a compact mono laser printer, aimed at small and home offices. Its basic and rather clumsy looks are somewhat deceptive, as they disguise a printer that's a rung or two up from entry level. The B3340DW has a claimed 38ppm top speed and is covered by a three-year warranty once you register it with Lexmark.

As the DW suffix suggests, this printer supports Wi-Fi, and can make automatic duplex prints. Its paper handling features aren't bad either, as there's a 250-sheet cassette and 100-sheet multipurpose feed. Lexmark even says this printer can handle a 50,000-page one-off monthly maximum, although it recommends a more prosaic duty of 500 to 5,000 pages.

The B3340DW has a two-line mono display fixed flat on its upper panel. This takes a while to get going when you first switch it on, and seems unnecessary given it isn't accompanied by a USB host port, but is helpful when you first connect to a wireless network.

This is a fast text printer, reaching an impressive

ABOVE All angles and flaps, the B3340DW is no beauty

RIGHT It's a shame there isn't a USB host port to go with the basic display

30.6ppm on our 25-page test, the joint fastest device in this group test. It hit 33ppm over 50 pages, faster even than the Labs-winning Brother HL-L9340CDN.

In truth, however, this printer doesn't have much else going for it. It rather laboured over our graphics tests, producing greyscale pages at only 12ppm, and reaching a modest 8.6ipm when duplexing. Photos were quicker, with two 10 x 8in prints completed in just 20 seconds, but the results weren't especially impressive: graphics were a shade too dark and had subtle fine banding. In addition, the printer's half-toning gave a slightly grainy impression that reminded us of charcoal shading.

We wish we could point to low running costs, but despite a 40,000-page drum and an extra-high yield toner rated for 6,000 prints, these still work out at 2p per page. That's not excessive in this class, but it would certainly add up quickly if the printer saw heavy use. That's unfortunate given the B3340DW would otherwise be well suited to producing a lot of black text in a hurry.

Xerox C230DN

Xerox can do much better than the slow and disappointing C230DN

SCORE ★★☆☆☆
PRICE £221 (£265 inc VAT)
from printerbase.co.uk

We're quite used to Xerox printers winning laser shootouts, but in recent months its form seems to have deserted it. Witness the C230DN, a colour laser printer aimed at small offices and workgroups. It's not especially fast, with a claimed 22ppm top speed in black or colour, but it still comes with duplex printing, plus wired and wireless networking.

The C230DN sits a class below the C310DN we reviewed in last year's printers group test, but it shares its slightly disappointing paper tray configuration. There's a 250-sheet cassette in the base, but only a single-page bypass slot for headed or special media. Behind the front flap you'll find a set of four consumables, each combining toner and an imaging drum. You get a desultory 500 pages in the box, while even high-capacity replacements last for only 3,000 black or 2,500 colour pages. At nearly 13p for a full colour page, the resulting running costs are steep.

Start printing and the C230DN sounds like someone vacuuming the carpet upstairs. At least, it does once it gets going – this printer suffered from

ABOVE It's compact and smart, but this slow printer doesn't produce great results

RIGHT The display is helpful during Wi-Fi setup, but not for much else

particularly long spool times, with a 32-second wait between clicking Print and receiving the first page of the printout. From cold it needs another ten seconds or so of warm-up time before starting a job.

Even when up and running, the C230DN was plain slow. Its best effort was 11.9ppm on our 50-page document, barely half its rated speed. Over 25 pages of text it managed a mere 10.5ppm, while its 6.6ppm colour graphics performance was more akin to an inkjet. Talking of which, at 2.8ipm, it was awfully slow when duplexing.

We wish we could say the results are worth it but, no, not really. While black text was typically laser-sharp, the colours in graphics were off, with the default settings giving illustrations a greenish pallor. This was even more pronounced in photos, where skin tones tended towards the seasick. No amount of fiddling with the various colour options produced satisfactory results. Sadly, that leaves the C230DN even more disappointing than the C310DN. Unless you're insistent on a laser, Canon's Maxify GX5550 makes a far better office colour printer.

Print speed tests

■ Inkjet printer ■ Laser printer

Text speed (mono, ppm)

Printer	Value	Note
Lexmark B3340DW	31	
Brother HL-L9430CDN	30	Labs Winner
HP LaserJet 5700dn	30	
Kyocera P2235dn	29	
HP LaserJet 4302fdw	25	
HP OfficeJet Pro 9012e	21	Recommended
Canon GX5550	20	Recommended
Brother DCP-J1800DW	15	
Epson ET-14100	14	
Canon GX2050	13	
Canon TS8750	13	Recommended
Epson ET-2830	12	Labs Winner
Xerox C230DN	11	
Epson ET-18100	7	

Graphics speed (colour, ppm)

Printer	Value	Note
Kyocera P2235dn	28	
Brother HL-L9430CDN	21	Labs Winner
HP LaserJet 4302fdw	14	
HP LaserJet 5700dn	14	
Lexmark B3340DW	12	
Xerox C230DN	6.6	
Brother DCP-J1800DW	6	
HP OfficeJet Pro 9012e	6	Recommended
Epson ET-18100	5	
Canon GX5550	4.9	Recommended
Canon GX2050	4.8	
Epson ET-2830	4	Labs Winner
Epson ET-14100	4	
Canon TS8750	3.9	Recommended

Two-sided printing (colour, ipm)

Printer	Value	Note
Brother HL-L9430CDN	14	Labs Winner
Kyocera P2235dn	13	
Lexmark B3340DW	8.6	
HP LaserJet 5700dn	8.2	
HP LaserJet 4302fdw	7.8	
Brother DCP-J1800DW	3.6	
HP OfficeJet Pro 9012e	3.4	Recommended
Canon GX2050	3.2	
Canon GX5550	3.2	Recommended
Xerox C230DN	2.8	
Canon TS8750	2.4	Recommended
Epson ET-2830	N/A	Labs Winner
Epson ET-14100	N/A	
Epson ET-18100	N/A	

Two 10 x 8in photos on A4 (ppm)

Lower is better

Printer	Value	Note
Lexmark B3340DW	20secs	
Kyocera P2235dn	22secs	
Brother HL-L9430CDN	23secs	Labs Winner
HP LaserJet 4302fdw	34secs	
HP LaserJet 5700dn	34secs	
Xerox C230DN	44secs	
HP OfficeJet Pro 9012e	3mins 16secs	Recommended
Canon GX2050	3mins 39secs	
Canon GX5550	3mins 40secs	Recommended
Epson ET-18100	5mins 6secs	
Epson ET-2830	6mins 11secs	Labs Winner
Epson ET-14100	6mins 18secs	
Canon TS8750	7mins 15secs	
Brother DCP-J1800DW	7mins 38secs	

Six 6 x 4in borderless photos* (ppm)

*On three sheets of A4 for lasers

Lower is better

Printer	Value	Note
Lexmark B3340DW	20secs	
Brother HL-L9430CDN	21secs	Labs Winner
Kyocera P2235dn	21secs	
HP LaserJet 5700dn	36secs	
HP LaserJet 4302fdw	39secs	
Xerox C230DN	57secs	
HP OfficeJet Pro 9012e	6mins 11secs	Recommended
Canon GX2050	6mins 26secs	
Canon GX5550	6mins 6secs	Recommended
Epson ET-18100	7mins 53secs	
Canon TS8750	10mins 24secs	Recommended
Brother DCP-J1800DW	12mins 15secs	
Epson ET-2830	14mins 15secs	Labs Winner
Epson ET-14100	15mins 6secs	

Time to first page (mono, secs)

Lower is better

Printer	Value	Note
Lexmark B3340DW	11secs	
Brother DCP-J1800DW	12secs	
Epson ET-14100	12secs	
Canon GX2050	13secs	
Canon TS8750	13secs	Recommended
HP OfficeJet Pro 9012e	13secs	Recommended
Canon GX5550	14secs	Recommended
Brother HL-L9430CDN	14secs	Labs Winner
Epson ET-2830	16secs	Labs Winner
HP LaserJet 4302fdw	17secs	
HP LaserJet 5700dn	17secs	
Kyocera P2235dn	17secs	
Epson ET-18100	20secs	
Xerox C230DN	32secs	

Scanning tests

Preview

Lower is better

Printer	Value	Note
HP LaserJet 4302fdw	8secs	
HP OfficeJet Pro 9012e	9secs	Recommended
Canon GX2050	10secs	
Brother DCP-J1800DW	13secs	
Epson ET-2830	14secs	
Canon TS8750	17secs	Recommended

A4 150dpi

Lower is better

Printer	Value	Note
HP OfficeJet Pro 9012e	9secs	Recommended
Brother DCP-J1800DW	10secs	
Epson ET-2830	12secs	
Canon GX2050	14secs	
Canon TS8750	20secs	Recommended
HP LaserJet 4302fdw	No option available	

A4 300dpi

Lower is better

Printer	Value	Note
HP OfficeJet Pro 9012e	10secs	Recommended
Brother DCP-J1800DW	15secs	
HP LaserJet 4302fdw	15secs	
Canon GX2050	19secs	
Epson ET-2830	22secs	
Canon TS8750	25secs	Recommended

6 x 4in 600dpi

Lower is better

Printer	Value	Note
HP OfficeJet Pro 9012e	12secs	Recommended
HP LaserJet 4302fdw	17secs	
Brother DCP-J1800DW	24secs	
Canon TS8750	28secs	Recommended
Canon GX2050	30secs	
Epson ET-2830	37secs	

View from the Labs

We're living in a cost of printing crisis, but the answer is on hand – either through subscriptions (choose wisely) or refillable inks

Working out the running costs for a printer group test is always a marathon effort. Every test promises several hours of researching the cheapest toners, inks and other consumables for each device, adding prices up and dividing by page yields to get indicative page costs for a batch of printers.

I've been crunching these numbers for 20 years, but I doubt the typical consumer ever bothers – which is one reason why ink and toner subscriptions are really appealing. For a fixed monthly fee, you get a set number of pages, and a clear rate for extras should you need them. It's easier to understand, and easier to compare between printers – but is it as appealing as it looks?

Sign up to a plan, print the number of monthly pages it offers, and you'll almost certainly get better value than you would if you bought your own supplies. Take the HP OfficeJet Pro 9012e, which will print a page of text and graphics for around 5p. That's very competitive for a cartridge-based printer, yet all but the cheapest of HP's Instant Ink plans gives you a lower cost per page. On the 700-page Business tier, it's just 2.7p.

But what if you don't print all the included pages? You can roll some over to the next month, but only up to a point. If you subscribe to the Business plan but print only 300 pages a month, it works out at 6.2p per page.

Simon Handby probably reviews more printers than anyone else in the UK

The HP 9012e costs 17 times as much per colour page as Epson's EcoTank ET-2830

"My preference is for ink tanks. Yes, you pay more for the printer, but it comes with enough ink that it's better value out of the box"

Things are complicated further by the fact that subscription plans charge a per-page fee, regardless of whether you print text, graphics or photos. Again, colour prints are almost certain to be better value if you're on the right tier, but buy your own cartridges and the 9012e can print black text for a penny – Instant Ink doesn't get close.

Either way it's a challenge to avoid paying over the odds, which is why my preference is for ink tanks. Yes, you pay more for the printer, but it comes with enough ink that it's better value out of the box. And once you've drunk the in-box bottles dry, your ongoing running costs are measured in fractions of a penny per page.
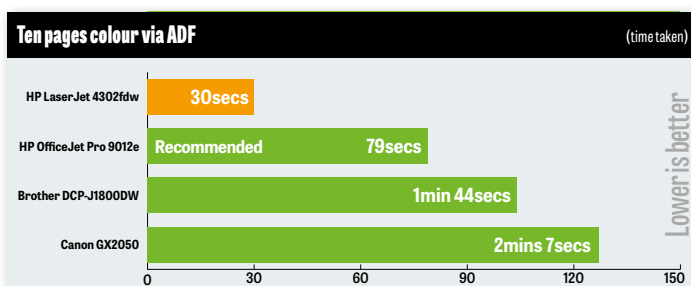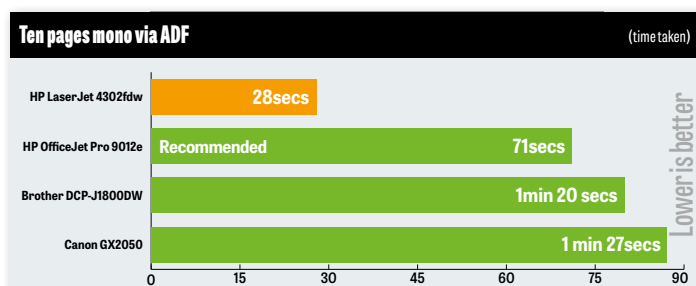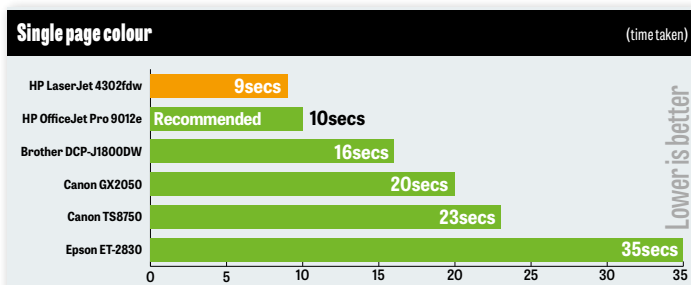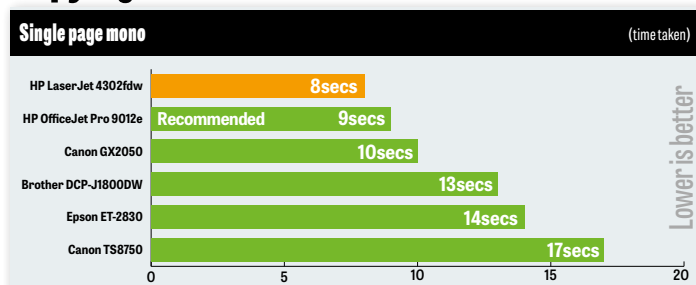
In fact, refillable printers have redefined what it's reasonable to pay for ink. Consider Epson's EcoTank ET-14100. This will print you a page of black text for around 0.1p, which is the lowest cost per page I've ever recorded. That's nine times less than you'll pay with the Brother HL-L9430CDN, and fully 35 times cheaper than the Canon Pixma TS8750.

For colour printing, take the EcoTank ET-2830's 0.25p per page milestone. Even the HP 9012e will set you back 17 times as much for every colour page. Pick the Xerox C230DN and it's 40 times.

Print costs aren't everything, of course, and you might still pick a cartridge inkjet or a laser for its speed, durability, features or print quality. If you're a light user, you may never reach the volumes at which a refillable device makes sense. But for me, writing our group tests, it feels increasingly hard to make the case for printers that cost an order of magnitude more per page than necessary. ●

Copying tests

Single page mono (time taken)

Printer	Time
HP LaserJet 4302fdw	8secs
HP OfficeJet Pro 9012e (Recommended)	9secs
Canon GX2050	10secs
Brother DCP-J1800DW	13secs
Epson ET-2830	14secs
Canon TS8750	17secs

Lower is better

Single page colour (time taken)

Printer	Time
HP LaserJet 4302fdw	9secs
HP OfficeJet Pro 9012e (Recommended)	10secs
Brother DCP-J1800DW	16secs
Canon GX2050	20secs
Canon TS8750	23secs
Epson ET-2830	35secs

Lower is better

Ten pages mono via ADF (time taken)

Printer	Time
HP LaserJet 4302fdw	28secs
HP OfficeJet Pro 9012e (Recommended)	71secs
Brother DCP-J1800DW	1min 20 secs
Canon GX2050	1 min 27secs

Lower is better

Ten pages colour via ADF (time taken)

Printer	Time
HP LaserJet 4302fdw	30secs
HP OfficeJet Pro 9012e (Recommended)	79secs
Brother DCP-J1800DW	1min 44secs
Canon GX2050	2mins 7secs

Lower is better

Wi-Fi 6 & 6E access points for business

Don't wait for Wi-Fi 7, says Dave Mitchell.
Wi-Fi 6 and 6E points designed for business
use will be your best bet for years to come

SMBs that want their workforce to access data anytime, anywhere and on any type of device should take a "wireless first" approach to their network design. As smartphones, laptops and tablets become their preferred mode of working, staff expect wireless connectivity to be always available, with the majority demanding workplace mobility.

Designing a network that assumes most users and end devices will connect wirelessly doesn't need to be challenging: the technology to handle increased client densities, more demanding applications and greater traffic throughput is already here. Wi-Fi 6 was introduced over two years ago and is very mature, while Wi-Fi 6E – which extends wireless operations into the pristine 6GHz band – has been on the market for over a year.

This month, we look at both Wi-Fi 6 and 6E technologies and review business wireless access points (APs) from Asus, Netgear, Sophos and Zyxel. These are all affordable options for SMBs, and we've tested them in the lab to help you make the right buying decision.

■ **Should I wait for Wi-Fi 7?**
It might be tempting to wait for the next generation Wi-Fi 7, or IEEE 802.11be EHT (extremely high throughput), which will offer huge improvements in speed up to a theoretical 46Gbits/sec, as opposed to 9.6Gbits/sec for 6E. It supports the same 2.4GHz, 5GHz and 6GHz bands as 6E so it's backwards-compatible, but increases the 6GHz channel bandwidth from 160MHz to 320MHz and the maximum number of MU-MIMO spatial streams from eight to 16.

Transfer rates also get a speed boost. Wi-Fi 7 takes the 1024-QAM (quadrature amplitude modulation) from Wi-Fi 6/6E and quadruples it to 4096-QAM. Furthermore, whereas Wi-Fi 6/6E uses a single, dynamically selected band to connect users to an AP, Wi-Fi 7 introduces multi-link

operations (MLO), allowing a device to connect over an aggregated link using all three bands for greater performance, reduced latency and improved connection reliability.

You'll need to be patient, though, as Wi-Fi 7 isn't due to be ratified until around mid-2024. Although vendors such as Engenius, TP-Link and Zyxel have already announced Wi-Fi 7 business APs, you'll be paying a big

BELOW Netgear's WAX625 supports standalone mode
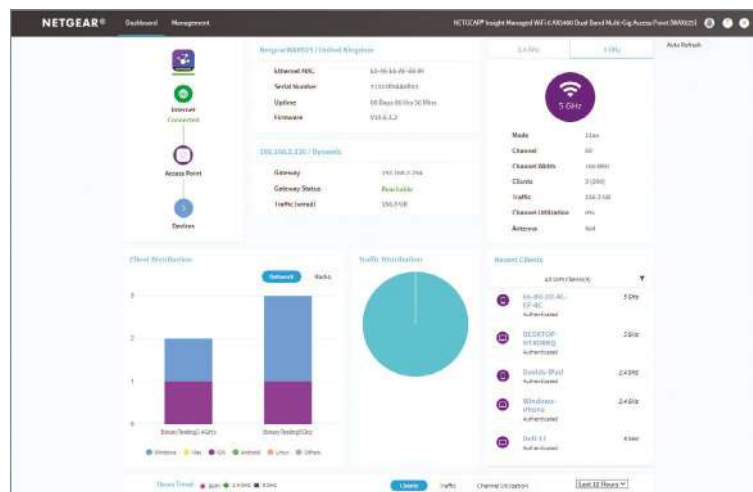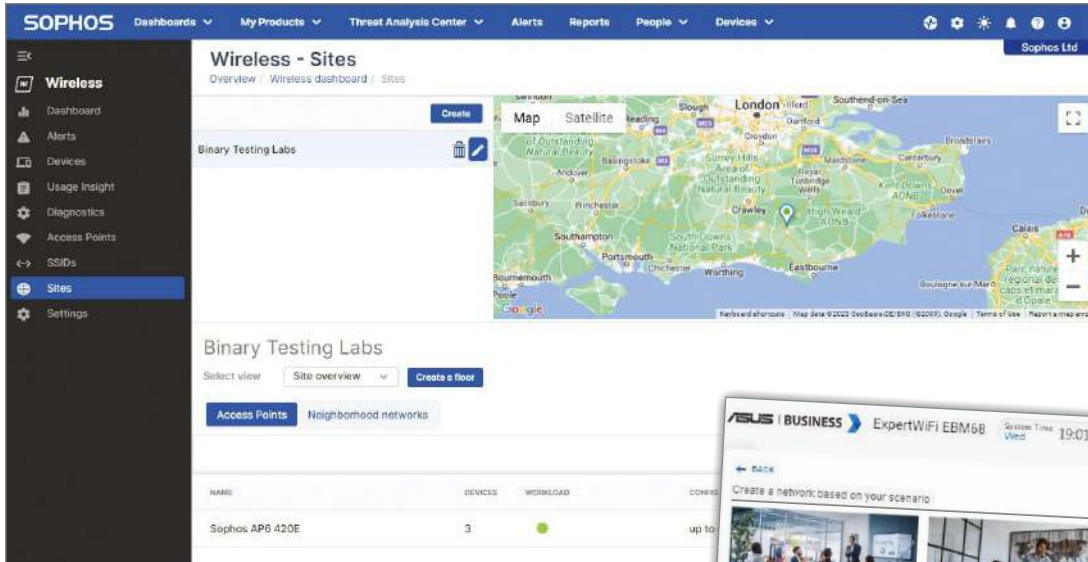
■ **Power move**

All business-class APs support PoE (Power over Ethernet), so a single cable can provide both the power and network connection. You can use PoE injectors if you have only a few APs, but larger installations should invest in a PoE switch that can power them all from a single wall socket.

If you're upgrading to Wi-Fi 6 or 6E, bear in mind that these APs require a lot more power than legacy Wi-Fi 5 models. A switch that delivers 802.3at PoE+ services will be enough for Wi-Fi 6 but most 6E APs require a minimum of 802.3bt PoE++ or else their performance may be impacted.

All good Wi-Fi 6/6E APs come with a 2.5GbE multi-gigabit network port as standard; choose a cheaper model with a gigabit port and all that extra bandwidth will be wasted. When selecting a multi-gig PoE switch you may want to think about future-proofing, as we expect most Wi-Fi 7 APs will have a high-speed 10-gigabit network port. Here in the lab we have all the bases covered: we use a Zyxel XS1930-12HP switch, which offers eight copper 10GbE multi-gigabit ports all presenting PoE++ services.

The inexorable rise of hybrid working and mobile workforces means businesses can no longer take a "wireless second" approach to their network services. The latest Wi-Fi 6 and 6E access points offer an affordable performance increase that will satisfy even the most demanding of users and customers, so turn the page to see which of the four solutions on review best fits your wireless domination plans.

price premium as an early adopter. Wi-Fi 7 client devices are also thin on the ground: the Google Pixel 8/Pro smartphones are out now, but Samsung's Galaxy S24 isn't due to be released yet while Apple's iPhone 16 Pro/Max probably won't be available until late 2024.

The bottom line is that if your legacy wireless network is creaking at the seams, then upgrading to Wi-Fi 6 or 6E is a very cost-effective way of delivering a big speed boost. If you're already using Wi-Fi 6/6E APs then we'd recommend waiting until Wi-Fi 7 has good market saturation in the business sector, unit prices have dropped significantly and there are a lot more client devices that support it.

■ **Walking on clouds**

A standalone AP may be fine for a small office, but larger businesses with many areas of a building to cover or big expansion plans should consider cloud management. This allows all APs and wireless networks to be centrally managed no matter where they're physically located, and is perfect for businesses with geographically distributed offices.

From a single web portal, you can create sites for each location, add secure wireless networks, decide which APs will broadcast them and keep a close eye on network health, client connections and bandwidth usage. For swift deployment, look for APs that support "zero-touch provisioning", which allows you to register them in the cloud portal,

assign them to a site and then send them to the remote location.

All the user needs to do is plug them in, ensure they have internet access and leave the cloud portal to push your configuration to them. This feature is ideal for businesses with home workers since they don't need any technical knowledge to install a cloud-managed AP.

■ **Mesh it up**

Look for a feature called meshing: if the AP supports this, you'll have a very easy time expanding your wireless network. More commonly available with cloud-managed APs, meshing requires one AP to act as a "master" or "root", which requires a cabled connection to the main network.

"Node" or "slave" APs can be added as required and just need a power source as they communicate wirelessly with the master AP and take all their settings from it. For the best performance, look for mesh APs that have a dedicated backhaul radio as they use this as a high-speed connection to the master AP.

"Look for a feature called meshing: if the AP supports this, you'll have a very easy time expanding your wireless network"

Asus ExpertWiFi EBM68

The EBM86 offers swift wireless network expansion and a wealth of security features for the price

SCORE ★★★★★

PRICE 2-pack, £540 exc VAT
from amazon.co.uk

Asus' main focus has traditionally been on consumer networking and wireless products, but that doesn't mean it isn't interested in businesses. Far from it, as its ExpertWiFi EBM68 and AiMesh system is aimed squarely at SMBs that want secure Wi-Fi 6 networks that can be swiftly expanded on demand.

This AX7800 tri-band access point (AP) claims speeds of 600Mbits/sec on its 2.4GHz radio, 2,402Mbits/sec on the first 5GHz radio and a whopping 4,804Mbits/sec on the second 5GHz radio. The latter provides a dedicated 4x4 MU-MIMO backhaul connection for meshed APs, while users get 2x2 MU-MIMO services on the other two radios.

Individual EBM68 units cost £290, and we reviewed the two-pack version which is priced at £540. This is only slightly less than Netgear's Orbi Pro SXK80 pack, but Asus offers a lot more for your money.

It supports 12 mesh nodes – twice as many as Netgear – plus you can create five SSIDs and present custom captive portals to guests. The dual WAN feature can load balance two internet connections using the 2.5GbE multi-gig WAN port and another of your choice from the integral three-port LAN switch, or you can connect a mobile to its USB-A port and use that as an internet backup.

The EBM68 also functions as an AP or router but, unlike the Orbi Pro SXK80, it's packed with network security measures. Along with a customisable firewall, the Trend Micro-powered AiProtection service blocks malicious websites, stops infected systems from accessing the network, provides intrusion prevention services (IPS) and generates security assessment reports.

It also supports PPTP, OpenVPN, IPsec and WireGuard VPN servers, while VPN Fusion creates secure connections for devices that can't run VPN client software. Quality of services (QoS) features are good, too, as Asus' Adaptive QoS uses a customisable list to prioritise traffic from different apps and activities.

Deployment starts with the unit sporting the "start with me" label and it can all be done from the ExpertWiFi mobile app. We linked an iPad to its

secure default SSID and ran through a wizard to activate the unit and update its firmware.

Wireless, or self-defined, networks are simple to create. You choose from a list that includes employee, portal, guest, scheduled and IoT options, fill in the fields presented and choose WPA2 or WPA3 encryption. The Scenario explorer makes this even easier as you choose an environment such as office, coffee shop or home working and it will present you with the most appropriate settings.

Adding the mesh AP is simple: you position it near to the root unit, provide power only and watch it pop up in the mobile app and web console's AiMesh topology page. You can then move it up to 15 metres away, preferably in line of sight, and although you'll incur a backhaul performance hit, it can be placed on another office floor.

Performance for the root node is fairly good. Close-range copies of a 25GB test file between a Windows 11 Pro workstation equipped with a TP-Link Archer TXE75E Wi-Fi 6/6E adapter and a server on the 10GbE LAN averaged 181MB/sec, dropping to 162MB/sec at a distance of ten metres.

To test AiMesh speeds, we placed the mesh node in a room one floor above the root AP. After connecting an iPad to it, the SweetSpots iOS app reported a steady 49MB/sec throughput over the backhaul link.

Small businesses will find a lot to like about the ExpertWiFi EBM86, as it's simple to manage and AiMesh makes it incredibly easy to expand wireless coverage. Wi-Fi 6 performance is reasonable and it includes an impressive range of network security features.

ABOVE Asus' tri-band AP offers speeds up to a huge 4,804Mbits/sec

> **"The Trend Micro-powered AiProtection service blocks malicious websites and stops infected systems from accessing the network"**

BELOW The EBM68 combines great security features with easy meshing

SPECIFICATIONS

AX78000 tri-band 2.4GHz/2 x 5GHz 802.11ax • 2x2/2x2/4x4 MU-MIMO • 6 x internal aerials • 2.5GbE WAN • 3 x gigabit LAN • USB-A 3.2 Gen 2 • wall-mounting plate • power adapter • 168 x 78 x 188mm (WDH) • 808g • 3yr hardware warranty
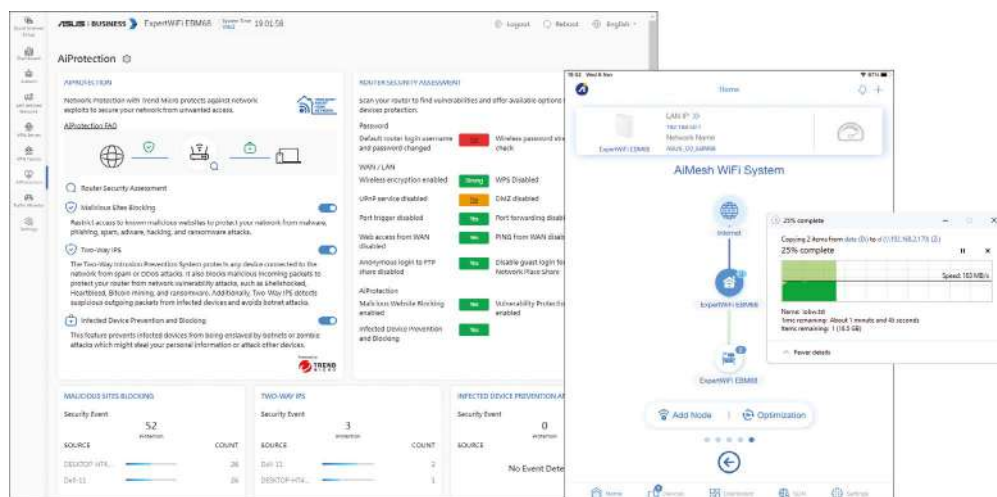
Netgear WAX625

A good-value, easily deployed Wi-Fi 6 AP with a fine turn of speed and great cloud management services

SCORE ★★★★☆

PRICE £224 exc VAT
from broadbandbuyer.com

Netgear's WAX625 could be the answer for SMBs that want a wireless performance boost but aren't keen on investing in Wi-Fi 6E hardware. This dual-band Wi-Fi 6 access point supports 5GHz 160MHz channels and its AX5400 rating promises a speedy 4,800Mbits/sec on its 5GHz radio and 600Mbits/sec on the 2.4GHz band.

It delivers four spatial streams for 5GHz plus two for 2.4GHz, and unleashes their speed potential with a 2.5GbE multi-gig LAN port which only requires a PoE+ power source. If you don't have a suitable PoE switch, Netgear offers an optional PAV12V UK power adapter that only costs a tenner.

Small sites can deploy the WAX625 in standalone mode and use its local web console for all management. Choose this method from the browser's quick start wizard and, after you change the default admin password, it creates an initial secure SSID and then presents a smart dashboard showing details such as connection status, client distribution by OS and traffic trend graphs for each radio.

Up to eight SSIDs are supported, and you can choose to make them available across both radios or only on selected ones, and you can also use different security settings up to the stronger WPA3. Advanced features include client isolation, rate limits, URL tracking and basic captive portals using click-through or external authentication.

Netgear's Insight cloud portal adds more appeal as you use it to remotely manage distributed wireless networks from a single web portal along with Netgear's Insight-enabled switches and routers. The WAX625 includes a one-year Insight subscription, with subsequent years costing £8.95 per managed device.

Adding the WAX625 to our account was simple. We used the Insight iOS app on an iPad to scan its QR code and, after it was recognised, we assigned it to a predefined site in our Insight organisation. With power and networking applied, the AP automatically connected to the site and started broadcasting its wireless SSIDs.

You'll find Insight offers the same level of access to the AP's features as standalone mode but adds extra services such as meshed network creation. One AP that's wired to the network is set as a root device, and you expand the network by adding node APs that connect wirelessly to it. Virtually all of Netgear's WAX-series of APs support meshing.

The informative Insight portal provides a summary page with the health of all cloud-managed Netgear devices, an overview of wireless activity and a topology map showing which APs clients are connected to. The Wireless page offers heaps of widgets so you can see graphs of wireless traffic for each AP, client connection trends, their individual data consumption and detected OSes.

Insight's captive portal features are extensive as guest SSIDs can have redirect URLs, custom logos, AUPs (acceptable use policies) and session timeouts assigned. Authentication options include basic click-through with redirect, web authentication using a third-party provider, an external Radius server or the paid-for RaGaPa cloud service.

We ran our real-world performance tests on the 5GHz band with the 160MHz channels enabled, and used a Dell Windows 11 Pro workstation equipped with a TP-Link Archer TXE75E Wi-Fi 6/6E PCI-E adapter as our host. The WAX625 delivered good results: copying a large 25GB test file between the host and a 10GbE-connected Windows server on the LAN averaged 212MB/sec at close range and a creditable 180MB/sec with the AP moved ten metres away into the next room.

The WAX625 is a great choice for SMBs seeking an easy wireless performance boost with minimum investment. It's an affordable Wi-Fi 6 AP with good speeds, while Netgear's Insight provides smart cloud management services.

ABOVE Netgear's WAX625 is a dual-band Wi-Fi 6 AP

"You can see graphs of wireless traffic for each AP, client connection trends, individual data consumption and detected OSes"

BELOW The WAX625 supports standalone and cloud management modes

SPECIFICATIONS
AX5400 dual-band 2.4/5GHz 802.11ax ● 2x2/4x4 MU-MIMO ● internal aerials ● 2.5GbE LAN/802.3at PoE+ ● gigabit LAN ● 12V DC power input (adapter not included) ● ceiling/wall-mounting plate ● 241 x 240 x 51mm (WDH) ● 890g ● 5yr hardware warranty. **Options:** Insight Premium, 1yr, £8.95 per device exc VAT
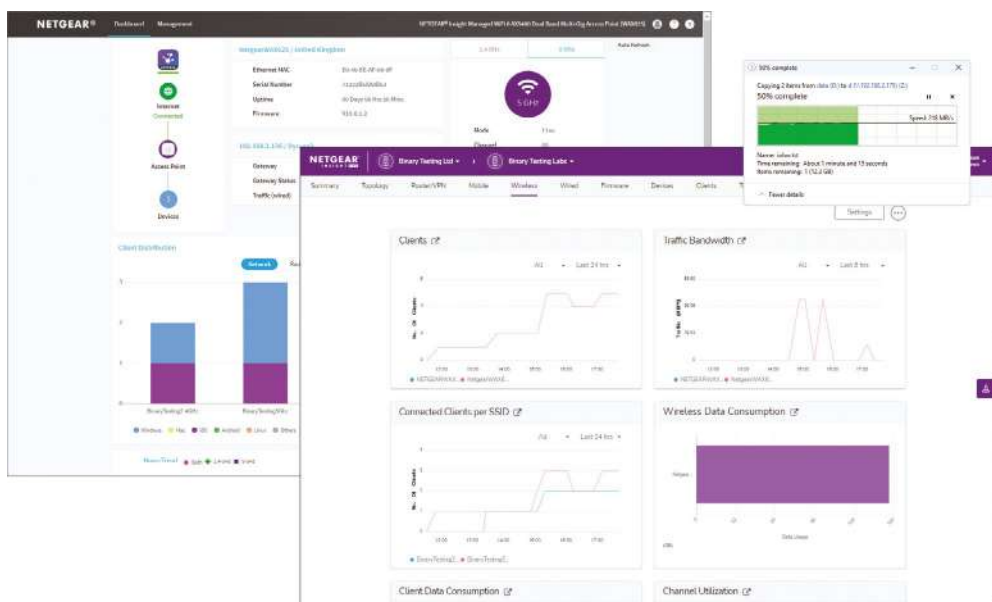
Sophos AP6 420E

Not the best value, but a capable Wi-Fi 6E AP with centralised cloud management services

SCORE ⭐⭐⭐☆☆

PRICE £598 exc VAT
from broadbandbuyer.com

Best known for its excellent security appliances and endpoint protection services, Sophos makes its first foray into Wi-Fi 6E territory with the AP6 420E access point. It teams up the 2.4GHz, 5GHz and Wi-Fi 6E 6GHz bands, supports 5GHz and 6GHz high-speed 160MHz channels and can be standalone or cloud managed.

The AP6 420E presents six spatial streams – two each for 2.4GHz, 5GHz and 6GHz, with claimed top speeds for each radio of 600Mbits/sec, 2,400Mbits/sec and 2,400Mbits/sec respectively. For a tri-band AP it's pleasingly compact and yet manages to squeeze in two omnidirectional aerials for each radio and a 2.5GbE multi-gig network port that requires a PoE+ power source.

Small businesses that only want one AP will find it easy to deploy as it defaults to standalone operations. Security is tight: its browser interface insists you change the admin password and gets you started with a preconfigured SSID that presents all three radios and applies a unique key using the AP's serial number.

There's a lot to play with here: you can create up to eight SSIDs for each radio and select WPA2 or the mandatory WPA3 encryption for Wi-Fi 6E networks. All radios support opportunistic wireless encryption (OWE), which allows you to present

a safe open public network that encrypts all endpoint traffic but doesn't require authentication.

Other features include client isolation, walled gardens and captive portals with custom landing pages, URL redirects and authentication using AP-generated daily, weekly or monthly passwords, vouchers, and Facebook and Google logins. Traffic shaping is extensive as different upload and download limits can be applied to each radio, selected SSIDs or their associated clients. The AP also supports SNMP v1/2/3 monitoring and can run packet capture sessions and save their output as Pcap files.

Sophos delivered good results in our real-world performance tests where we used a Dell Windows 11 Pro workstation with a TP-Link Archer TXE75E Wi-Fi 6/6E PCI-E adapter. With the 160MHz channels enabled on the 6GHz radio, large file copies

> **"There's a lot to play with here: you can create up to eight SSIDs for each radio and select WPA2 or WPA3 encryption"**

between the workstation and a Windows server on our 10GbE LAN averaged 210MB/sec at close range, dropping to 183MB/sec with the AP moved ten metres away and into an adjoining room.

The cloud management option will appeal to businesses invested in Sophos as all APs and wireless networks are managed from the same Sophos Central web portal. Onboarding isn't as smart as other wireless vendors that provide mobile apps and QR code scanning, as you enter the AP's serial number or bulk-provision up to 30 at a time using a CSV file.

The Sophos Central portal has been refreshed, with all the main menu options moved to the top for easier access. Selecting the wireless page presents a dashboard with status charts for all APs, alerts and the number of connected devices. The usage insights chart shows traffic categories for all clients, but this isn't currently supported for any AP6 model – and neither are rogue AP detection and roaming assist for sticky clients.

All other features present in standalone mode are available from the portal, however, so you can create the same number of SSIDs on all radios each with their own security settings. For easier fleet management, the portal also allows you to create different sites with associated maps and floor plans, with each assigned a set of APs.

The AP6 420E is comparatively expensive and a number of features for AP6 devices are yet to be implemented in the Sophos Central portal. That said, it delivers good overall performance and is a natural choice for businesses that already rely on Sophos for their network security.
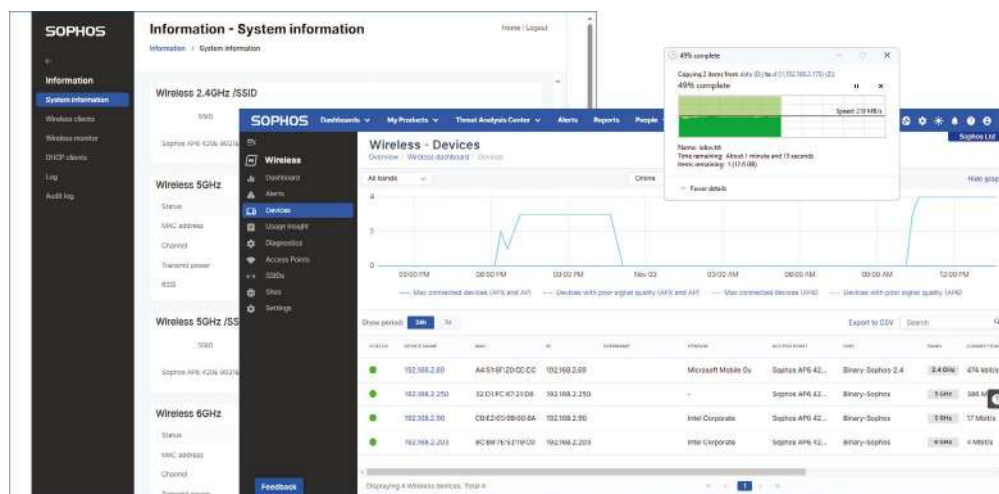
SPECIFICATIONS
AXE5400 tri-band 2.4/5/6GHz 802.11ax ● 2x2 MU-MIMO ● 6 x internal aerials ● 2.5GbE LAN/802.3at PoE+ ● micro-USB console port ● ceiling/wall-mounting plate ● 183 x 183 x 35mm (WDH) ● 700g ● limited lifetime warranty. **Options:** Sophos PO2ZTCHUK PoE+ injector, £111 exc VAT

Zyxel WAX640S-6E

Ideal for busy environments, this affordable tri-band AP offers good performance and cloud management

SCORE ★★★★★

PRICE £369 exc VAT
from broadbandbuyer.com

The WAX640S-6E is Zyxel's premium wireless access point (AP) and targets dense environments such as large offices, campuses and convention centres. This solidly built AXE7800-rated AP has a lot to offer as it combines the 2.4GHz, 5GHz and Wi-Fi 6E 6GHz bands, supports 5GHz and 6GHz high-speed 160MHz channels and employs Zyxel's smart antenna array that automatically detects whether it's wall- or ceiling-mounted.

The WAX640S-6E presents eight spatial streams – two each for 2.4GHz and 5GHz, while the 6GHz radio gets the lion's share of four streams. The AP's main 2.5GbE port requires an 802.3bt PoE++ power source and there's an extra gigabit LAN port for networking other wired devices.

Three management choices are available. The WAX640S-6E can be run in standalone mode or it can be remotely managed using Zyxel's on-premises NXC controller appliances. Larger businesses will find that Zyxel's Nebula Control Center (NCC) cloud management offers the best options as it provides a wealth of valuable features, and the price includes a one-year Professional Pack licence that enables email alerting, scheduled firmware updates and a one-year log-retention service.

Standalone deployment is swift. The web console wizard guides you through setting the country of operation and changing the default password. It creates radio profiles for all three bands, but be careful as the SSIDs it configures are open and must be secured immediately.

For our speed tests, we hooked the AP up to a Zyxel XS1930-12HP 10GbE multi-gigabit PoE++ switch and used a Dell Windows 11 Pro workstation equipped with a TP-Link Archer TXE75E Wi-Fi 6E PCI-E adapter. Performance over the 6GHz radio is good, with large file copies between the client and a 10GbE-connected Windows server returning average close-range speeds of 220MB/sec, dropping to a respectable 186MB/sec with the AP placed ten metres away in an adjoining room.

Moving the AP to our NCC account took only a minute; we used the Nebula iOS app to scan the QR code on its base and choose the site it should take its settings from. The portal is very informative, as its customisable dashboard offers widgets showing the status of all Zyxel cloud-managed devices, total wireless traffic, APs by usage and all connected wireless clients along with their detected OS.

ABOVE Zyxel's WAX640S-6E is a solidly built AXE7800-rated AP

PC PRO ★★★★★ **A-LIST**

"Larger businesses will find that Zyxel's Nebula Control Center cloud management provides a wealth of valuable features"

BELOW It can be managed in standalone or cloud mode and delivers good performance

You can create up to eight SSIDs per site, assign each one their own encryption key and use tags so SSIDs are only broadcast on APs that have a matching tag. For guest networks, you can present custom captive portals with your own logos and messages, use a variety of authentication methods and enforce L2 isolation so guests only get internet access.

From the radio settings page you can select different deployment densities that configure all APs accordingly, and we noted that NCC is Wi-Fi 7-ready as the 6GHz settings have a 320MHz channel option. You can enable the 5GHz 160MHz channels but only for individual APs, and due to the increased risk of interference, NCC will disable dynamic channel swapping (DCS) and require you to select a specific channel.

One feature you won't get with standalone mode is Zyxel's smart meshing. The WAX640S-6E lets you directly connect one AP to your gateway, designate it as a root device and add repeater APs as required that wirelessly connect to it for an easy increase in network coverage.

The WAX640S-6E is a reasonably priced tri-band wireless AP ideally suited to businesses that want to provide the full range of wireless services. It's easy to deploy, wireless performance is good and Zyxel's NCC provides top quality cloud management services.

SPECIFICATIONS
AXE7800 tri-band 2.4/5/6GHz 802.11ax ● 2x2/2x2/4x4 MU-MIMO ● internal aerials ● 2.5GbE LAN/802.3bt PoE++ ● gigabit LAN ● 12V DC power input (adapter not included) ● ceiling/wall-mounting plate ● 270 x 150 x 47mm (WDH) ● 900g ● 1yr NCC Professional Pack licence included ● limited lifetime warranty
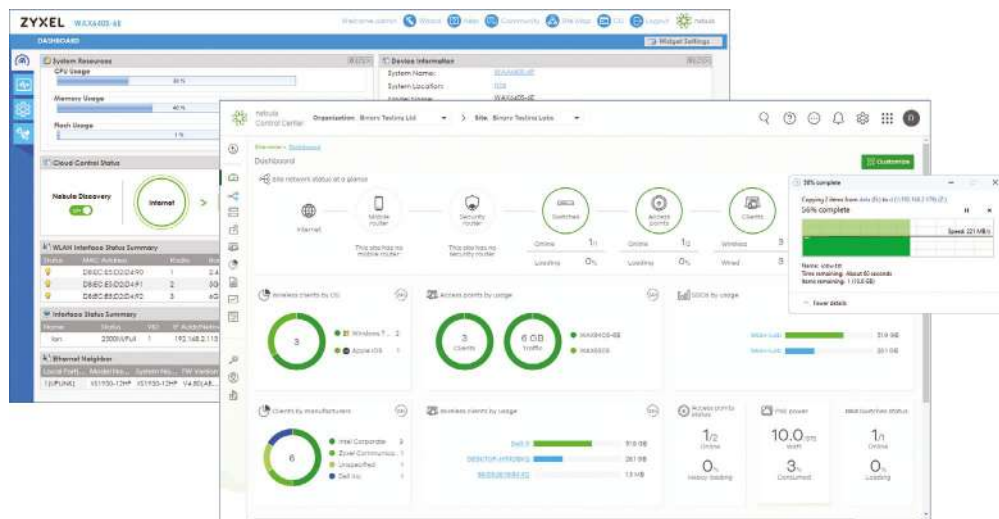
Poly Studio X52 with TC10

A smart solution for medium-sized rooms, with great video quality and support for all the main VC cloud providers

SCORE ✪✪✪✪✪

PRICE Studio X52 with TC10, £3,161 exc VAT from meetingstore.co.uk

As the latest member of the HP Poly Studio family, the X52 video bar delivers an advanced all-in-one solution for medium-sized meeting rooms. Taking over from the Studio X50, it features an uprated 20MP 4K UHD camera, a more powerful Qualcomm 865 CPU, improved dynamic framing algorithms, advanced microphones and Wi-Fi 6 support.

Apart from the larger camera there's little to tell the two models apart but at 95°, the X52 has a narrower FoV (field of view) than the X50. This is because the X52 is designed to deliver a higher resolution when zooming in to participants at the far end of the meeting table.

Its mic array claims a six-metre pick-up range, while sound output is handled by two 20W ported speakers. You have two HDMI-out ports for dual monitor support, HDMI-in and USB-C for host connections, a gigabit network port and a port for Poly's optional extension mic. All are easily accessible at the rear.

The X52 runs Poly's Android-based VideoOS software, which supports BYOD (bring your own device) mode and includes built-in video apps. The guest list is impressive, and includes Microsoft Teams, Zoom Rooms, Google Meet, GoToRoom, RingCentral Rooms and BlueJeans Rooms.

Deployment is simple: you connect power and network, wait a minute while it boots up and point a browser at its IP address. The web interface presents a system status dashboard with the active video app and you move to the Provider section to choose another app from the drop-down list.

You can swap between them as required and, although a reboot is necessary, it only takes two minutes to regain access. BYOD mode is always available with the X52 automatically swapping to it when it senses a USB connection and, once you've finished, you can exit back to the app.

We had no problems cloud-managing the X52 by registering it with our Lens portal account. You can remotely manage all your Poly devices, assign them to sites and rooms, run remote firmware updates and upgrade to the premium Lens service for detailed meeting analytics.

We tested with Microsoft Teams and used the registration code presented on the screen to assign it to our Microsoft 365 account, where the X52 appeared as a new Teams Rooms on Android device. We also paired the X52 with Poly's TC10 PoE-powered controller tablet and used the same registration process.

Our Teams console showed both devices as online and paired, after which the tablet moved all meeting

controls to its own display. We had no problems creating and joining Teams meetings using the tablet's 10in touchscreen, and in BYOD mode we could use its menu to manually control the camera and create up to ten presets for specific camera positions.

Video quality is excellent, and we noted the camera's focus is markedly sharper than the Poly P15 we use in the lab. The mics worked well, as remote participants could hear us clearly when we were 4.5 metres away, while the dual speakers delivered a clean sound quality that easily filled our 24m² meeting room at a 60% volume level.

> **"Video quality is excellent, while the dual speakers delivered a clean sound quality that easily filled our 24m² meeting room"**

The X52 gets the benefit of Poly's NoiseBlockAI and Acoustic Fence technologies, which remove annoying background noises, while the DirectorAI feature handles group and speaker tracking. Also accessed from its web console, the DirectorAI Perimeter option allows you to define a custom tracking zone.

Although still in a preview testing phase, the X52 offers people framing, which shows all participants using up to six split screens. Whichever mode you choose, you'll be impressed with its speed as the camera snaps to active speakers in no more than two seconds.

Poly's Studio X52 is perfect for businesses that want a professional video conferencing solution for their medium-sized meeting room. Video quality is excellent, speaker tracking is impressively fast and the big choice of built-in VC apps makes it incredibly versatile.
DAVE MITCHELL

BELOW The Studio X52 delivers excellent video quality and can be remotely managed

SPECIFICATIONS

4K UHD camera ● 95° FoV ● 5x digital zoom ● 2 x 20W speakers ● 2 x MEMS mics ● gigabit Ethernet ● Wi-Fi 6 ● Bluetooth 5 ● 2 x USB-A 3.2 Gen 1 ● USB-C (speed not stated) ● HDMI in ● 2 x HDMI out ● display clamp ● external PSU ● 770 x 103 x 115mm (WDH) ● 2.5kg ● **Poly TC10:** 10in colour touchscreen ● PoE Ethernet ● 1yr RTB warranty
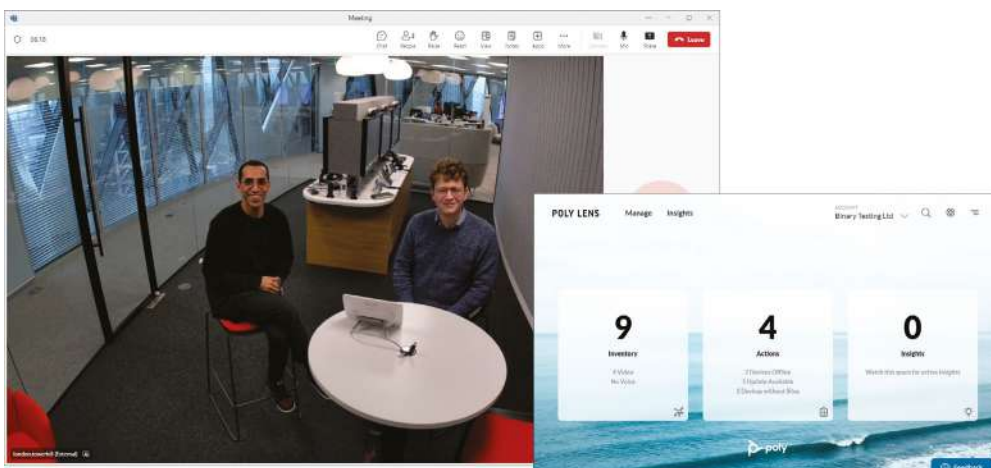
Zyxel FWA510

This versatile 5G router provides reliable internet access but Wi-Fi 6 performance is below par

SCORE ★★★☆☆

PRICE £385 exc VAT
from broadbandbuyer.com

Zyxel has been steadily building up an extensive range of 5G NR mobile routers, and the FWA510 is one of its most versatile yet. This desktop unit takes everything we liked in Zyxel's NR5101 (*see issue 338, p103*) and claims a doubling in Wi-Fi 6 performance, adds essential 2.5GbE multi-gigabit network ports and teams up its four embedded omni-directional antennas with an option to add four TS9 external aerials for improved reception.

The FWA510 is slightly larger than the NR5101, and the status LEDs have been moved from the front of the unit to the sloping upper surface. These will prove useful as they alert you if an SMS message has been received, use a multicoloured LED to show cellular signal strength and provide visual cues for internet connectivity and wireless status.

The rear interface panel has also been redesigned and now has a faster USB-A port for sharing storage devices. The second multi-gig port can function as a LAN or WAN interface and, if you choose the latter, it takes precedence over the cellular connection, which drops back to standby mode for automatic failover services.

The FWA510 is easy to install, with its local web interface provides a wizard to get you up and running. Our unit was supplied with a Vodafone 5G SIM snuggling in the 3FF slot in the base, which provided instant cellular internet access.

The web interface presents a dashboard showing the status of local and internet connections, cellular status and details of wireless networks. A default SSID is provided for both radios and, although it uses the weaker WPA2 encryption, you can easily swap to the more secure WPA3.

Four SSIDs are supported, with three guest wireless networks already configured. These can be modified to suit, with the Guest WiFi tickbox enabling L2 isolation

ABOVE There are four embedded antennas, with an option to add four external aerials

"General network security is good. An integral firewall offers three protection levels, and you can add custom firewall rules"

BELOW The FWA510 can be cloud-monitored from Zyxel's Nebula Control Center

so users on these SSIDs only get internet access.

General network security is good. An integral firewall offers three protection levels that you choose using a slider bar, and you can add custom firewall rules that comprise protocols and port numbers, plus access control list (ACL) entries to control connections for source and destination IP addresses and services.

So far, so good, but we came across an issue with the router's wireless services. Zyxel claims it delivers up to 2,400Mbits/sec on the 5GHz radio (hence the AX3600 rating), but to achieve this it must support the high-speed 160MHz channels.

At present, the web console's wireless settings for the 5GHz radio offer a 20/40/80MHz option, so our test clients could only connect at 1.2Gbits/sec. Consequently, copies of a 25GB test file between a Windows 11 Pro workstation equipped with a TP-Link Archer TXE75E Wi-Fi 6/6E adapter and a server on our 10GbE LAN maxed out at 108MB/sec at close range, dropping to 86MB/sec with the router ten metres away in the next room – only marginally faster than the AX1800-rated NR5101.

The FWA510 can be cloud-managed from Zyxel's Nebula Control Center (NCC), and we added it to our account by scanning its QR code from an iPad running the Nebula iOS app. A status widget can be added to the NCC site dashboard, and selecting it provides more hardware details along with views of WAN and cellular status, 24-hour traffic graphs and information about wired and wireless clients.

Unlike Zyxel's fully compliant Nebula wireless APs, the FWA510 doesn't broadcast the cloud SSIDs as these must be configured from its own web interface. Upgrade to an NCC Pro Pack licence and the remote configurator tool can load this directly from the NCC portal and will also increase traffic monitoring to 30 days.

Zyxel's FWA510 and its 5G NR support will appeal to home workers in rural areas and remote offices that demand always-on internet access. It's easy to use and can be cloud-monitored but, unless a firmware upgrade materialises, its Wi-Fi 6 services are no faster than the NR5101 it's replacing. **DAVE MITCHELL**

SPECIFICATIONS

AX3600 dual-band 2.4GHz/5GHz 802.11ax ● 4x4 MU-MIMO ● 4G/5G SIM slot ● 2 x 2.5GbE ports (LAN/WAN, LAN) ● USB-A 3.2 Gen 1 ● 4 x TS9 external antenna ports ● 133 x 134 x 230mm (WDH) ● 1kg ● external PSU ● 2yr RTB warranty

IT in the C-suite
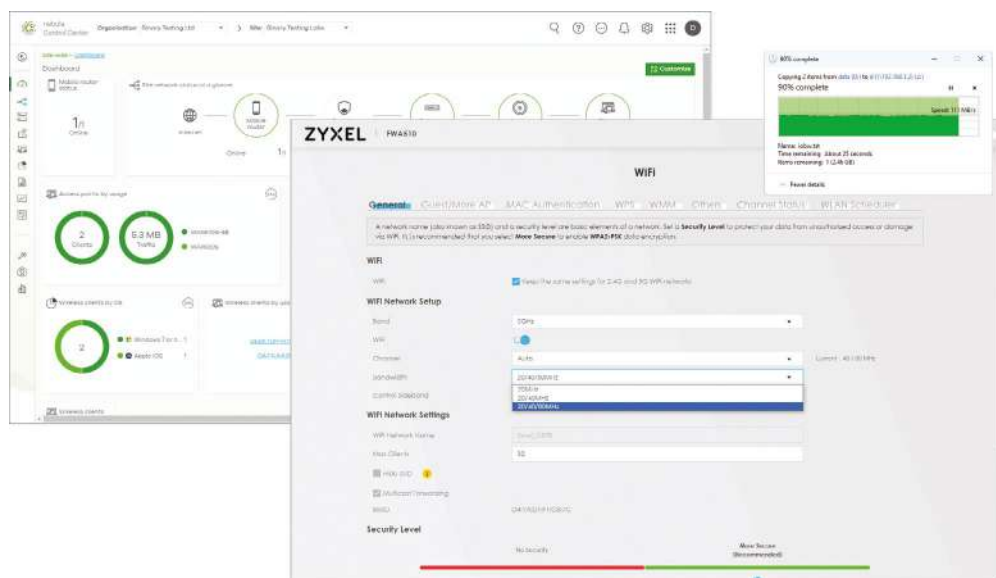
What do a CIO and CTO actually do – and do you need them? Steve Cassidy takes a look at the high-flying technology roles

IT managers have to deal with all sorts of issues, from hardware provisioning to remote security, but sometimes the biggest challenge is working with your own senior leadership.

The idea of the "C-suite" is that its inhabitants aren't just good at your business – they're good at business in the general sense, with wisdom to enrich any company they choose to work with. This explains why relatively small, fairly similar groups of people across many diverse business types and sizes get to command far more decision-making power and budget authority than their experience or job history might seem to justify.

They're not all the same, though. The CEO, or chief executive officer, is the real boss. He or she may also be called the MD in the UK, or the company president in the US. All the other C-something-O roles are fundamentally helpers to the CEO, because the jobs the boss is expected to do are so numerous and diverse that encompassing them all in one great messianic figurehead is impractical.

As a *PC Pro* reader, the ones you're most likely to be dealing with are the

chief technology officer and the chief information officer. Their responsibilities may overlap in places, but perhaps less than you'd imagine: a CIO can have work to do without there being a single computer in the building, as the job includes figuring out the legal impacts and statutory demands controlling all the ways companies generate, use and dispose of data.

A CTO, by contrast, is a nuts-and-bolts person, concerned with things such as physical hardware and suppliers, plus contracts for more airy provisions such as cloud presence and internet access. One principal place where this crosses over with the CIO is when bigger businesses invest in hybrid cloud setups, where on-premises equipment has to work in tandem with outsourced, contracted services.

■ One head, many hats

That's how it works in larger companies, but what about smaller businesses that aren't big or rich enough to employ a whole platoon of senior leaders? The usual way of managing a shortage of manpower at the top is for individuals to wear

multiple hats. This is a simple, affordable approach, but it has its limitations. I've seen plenty of tiny, five-person companies with an educated but overloaded genius in the top seat; in my experience it's quite possible for a driven individual to handle any or all of the C-suite roles – but, to steal an observation from Nobel prizewinner Richard Feynman, it's not possible to hold all those trains of thought and perspectives in your head at the same moment.

What this means in practice is that it's acceptable for the boss to wear different hats during a conversation or a management meeting, but not for them to switch back and forth without warning. Taking the time to clear the mental deck and reset expectations before starting down a separated path is essential for everyone to keep up, and indeed for the boss themselves to be clear on what priorities they're focusing on at that moment.

To reduce the burden and the complexity of the decision-making process, smaller businesses can find it beneficial to distribute

> **"I've seen plenty of tiny, five-person companies with an educated but overloaded genius in the top seat"**

C-suite-type remits to available employees. Sometimes an obvious fit presents itself; at other times, if we're being honest, it's like someone dressing up in a cartoon character suit at the front of the town parade. But it can still be helpful to have a nominated locus of attention for different aspects of the business.

■ Professional associations

If your business is in need of professional expertise, you don't necessarily need to hire an expensive, highly qualified executive. Take a look at the simple manifesto of my chums at the Real Time Club (**realtimeclub.co.uk**); this is an association of individuals sharing expertise and experience, to save everyone from having to repeat basic research and procedure development that has already been dealt with by friends and competitors.

They're far from the only such organisation. Once you're aware of the idea, you start seeing professional associations almost everywhere, from the Worshipful Company of Information Technologists to the NCVO (which handles information sharing between charities). Or the many-armed octopus of SABRE – born as the IT department of American Airlines, but which has now evolved into an international clearing house handling routing and ticket information for flights of all nations and types.

As you'll gather from that last example, not all associations will be equally useful to everyone. Be aware, too, that quite a lot of them tend towards drinking clubs, although that shouldn't necessarily put you off: drunk techies like to share their secrets at least as much as sober ones.

At the extreme, a trade association may even handle custom software development and upkeep processes for a particular industry. In all cases, being part of a larger body lessens the requirement for internal C-suite roles to act as authoritative, executive experts on everything within their purview. For smaller companies in particular that's a huge benefit: if your line of business doesn't have a supporting professional body, you should seriously consider starting one.

■ Being fractional

The idea of the C-suite isn't beyond criticism. It's been suggested that if a person's time needs to be solely dedicated to making management decisions then the business itself is

ABOVE Tech-savvy managers are vital in businesses big and small

BELOW Individuals at the top of a company often have to wear a multitude of hats

wrongly structured, or the individual isn't up to the job. The latter isn't out of the question – few companies are immune to nepotistic hiring policies. And as I've noted, it's possible for a single person to occupy multiple roles, at least when things are going smoothly.

Even with the most qualified crew guiding the ship, however, businesses can for all sorts of reasons find themselves in uncharted waters. At that point, the role under stress needs to be able to draw upon some additional IT-savvy brains with a fresh perspective, perhaps in the position of an interim CTO.

This isn't an unusual position to be in. I've been doing this kind of work as a consultant since the mid-1990s, and I've seen a great many interim or part-time C-suite appointments. In my experience, around a third of them are made to overcome a short-term emergency. Another third are very short-lived, generally because the appointment was really a disguised way of asking one specific question. The final third stick around forever: I know one interim CTO who's been there for 12 years, while another is on 21 years and counting.
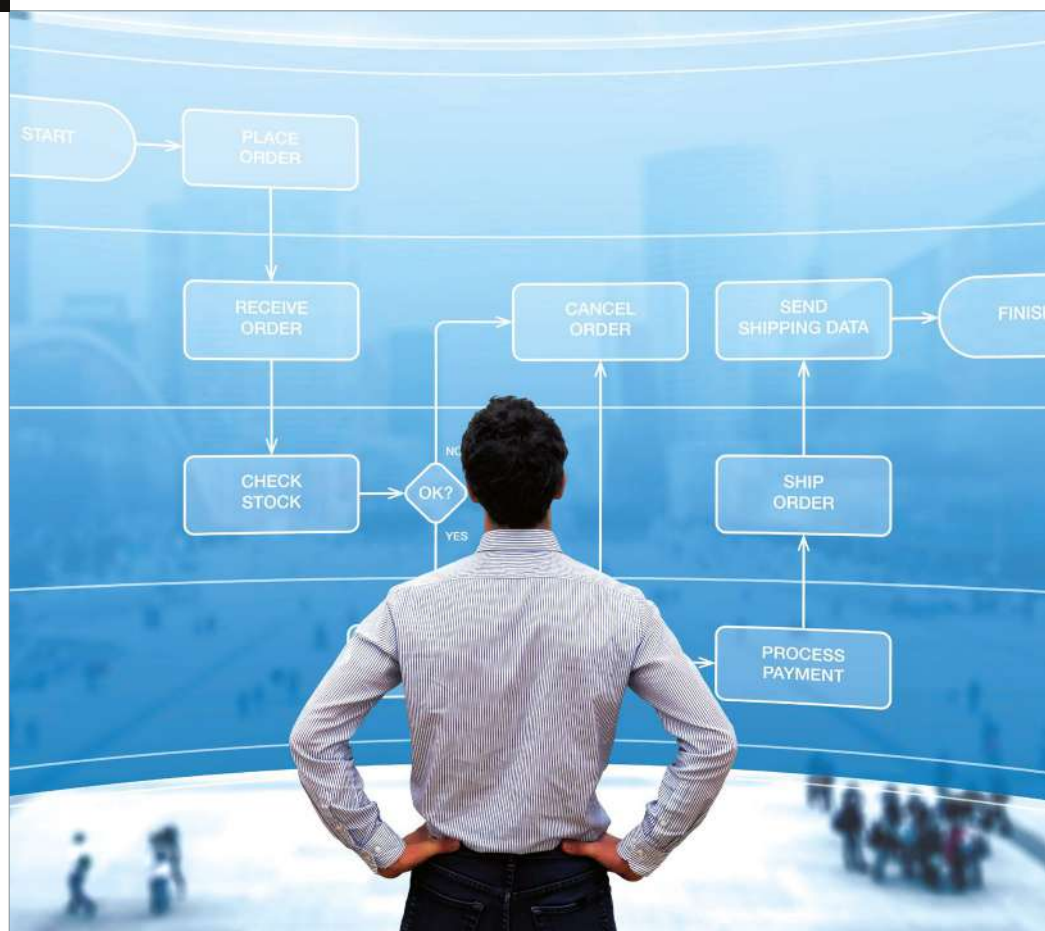
And there's no shame in this. To me, it merely confirms that not every C-suite role needs to be a full-time, single-focus employee. Sure, a CIO might have legal papers to sign, and obligations that require them to be fully embedded in the company, listed as a board member and so on, but for the more techie roles – CTOs, CISOs and so on – much of their value lies in their connection to the IT industry, rather than whatever industry the host business happens to be in. It's better to have someone who's spending time out in the world, communicating with other geeks and staying in touch with all the latest trends and technologies in computing, than someone sitting at a desk in a factory day in, day out.
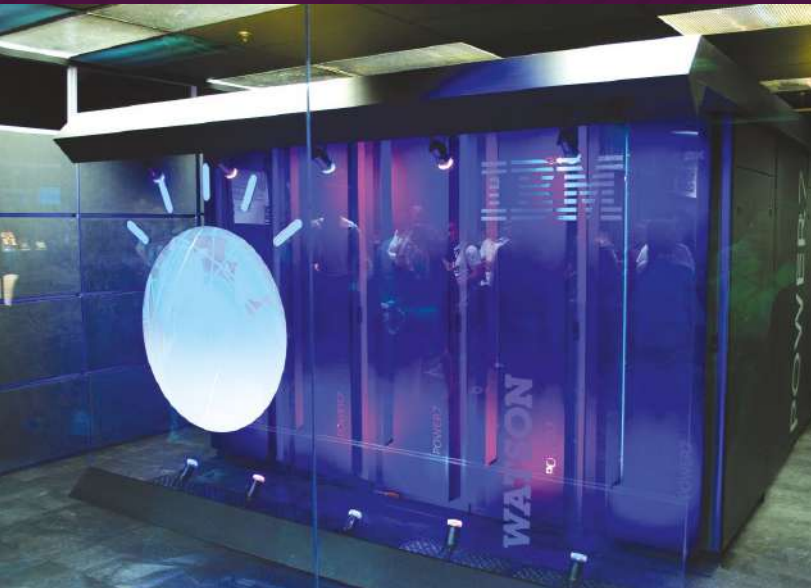
■ AI advisors

When I refer to AI advisors, I'm not suggesting you should bring ChatGPT into the command centre. Generating superficially convincing but ultimately mindless statements is not the sort of assistance C-suite executives need.

But AI does have a role to play, with machine intelligence increasingly factoring into C-suite decision making of all kinds. At a

➔

shallow level, the simple fact of AI involvement will be seen as a positive by certain types of customer and investor. But there's real value to be had, too. Take a look at the way IBM has built up its Watson product line; this is a traditionally coded AI, not reliant on the sort of "black-box" learning that characterises the newer, sexier cloud services. Watson is aimed at more serious tasks, such as identifying the most statistically likely outcome given a set of indicators for a special and limited field. When a business needs hard data, a Watson-type AI can trawl the web not for words and phrases to recombine, but for statistics, with a tightly defined relevance filter, to help the boss make informed decisions.

This is a much more subservient job description for AI than the kind of hype we've been seen lately, but that's fine: most of us don't want the top seats in our company to be occupied by an AI. What we do want is some sign of modern technological savvy, and for our board members to be working from the best available information and analysis.

■ Making the C-suite work

I've mentioned how C-suite members each have their own particular areas of interest and responsibility, but in reality there's a good deal of overlap and interaction between roles, even when the headcount is enough to achieve one head per hat. This isn't a sign of disorganisation or excessive spending: it's necessary to make joined-up decisions that work for the whole business.

For this reason, C-suites have to work closely together in ways that may be unique within the organisation. It's a textbook role for groupware – software that helps with shared document editing, secure inter-member messaging and the

occasional inclusion of external third parties. Products such as Dropbox, Teams, Zoom, WeTransfer and Telegram all have great appeal for a group of high-level workers who don't clock off when they go home.

While such ad hoc tools may help get the job done, there's a strong argument here for a more integrated, cloud-based solution. Whether that's Microsoft 365 or a super-duper flexible-working hosted HR service, it means senior IT staff don't have to worry about managing security across half a dozen different apps and access models. After all, almost all the work going on between C-suite workers is sensitive, because aside from the security role (CISO) their main interest is in evaluating change, and responses to change. It's not surprising that they don't tend to include the rest of the workforce in their ongoing conversations.

> "When a business needs hard data, AI can trawl the web for statistics to help the boss make informed decisions"

Whichever route you take, getting everything to work together smoothly and securely is no small demand – it's about understanding how a pattern of accounts and permissions that might be a disaster for the shop floor can facilitate the perfectly legitimate working practices of a senior management team. Conceivably there might even be some resentment at the idea of the C-suite having its own systems outside of the regularly applied policies and practices, but hopefully it's generally accepted that commercial objectives trump emotional agendas. Trusting an SaaS provider shouldn't be seen as a sign of disloyalty or eccentricity: indeed, it's often more carefully managed than internal systems.

If you're charged with supporting the C-suite, you may find it best to align yourself with their software platforms as far as possible. They will have done a lot of legwork to settle on one product over another; running your own videoconferences, or keeping your team's internal documentation in a collaboration service like Google Docs, expresses a certain sense of there being no barriers, no misapprehensions to trip over, when it comes to the management team, and you. ●

The password dilemma

We put the loose-cannon company officer on a plane to Monaco. This gave us a 24-hour period when we knew he would be in the air, or watching the F1 race, or drunk in his hotel room. We then arranged for him to be arrested at 6am, and frog-marched to another plane, still in his dressing gown and hotel slippers. While that plane was in the air, a retired Swiss policeman was combing through the hard disk in his company laptop.

All of this James Bond nonsense was because this guy had recently been told he was going to be fired – and was then caught on CCTV surreptitiously swapping out the hard disk in his work PC. He alone held the passwords to the domain registrar accounts, containing some 6,000 domain names; with these credentials he could, if he wanted, redirect the company's online presence to anywhere, or delete it entirely. He'd been able to set all this up because he was de facto CTO, and had the latitude of action to centralise all the domain registrations without having to explain himself to anyone.

If he'd kept a spare copy of the passwords, we never found it. In the end we had to call the registration provider, and then get them to call us back on the main switchboard number as partial proof of who they were talking to. We asked them to change the control panel passwords for all those accounts immediately, and send us the new passwords via one of the most secure channels available: a piece of paper delivered in person by a courier on a bike.

This duly arrived about three hours later. The courier had no problem finding our registered business address (it was the office building with all the lights on in the middle of the night). The crisis was averted, with no further action required except to safeguard the new passwords. After all, we didn't want to repoint any of the domains, we just wanted them left unmolested.

The lesson is that C-suite IT always needs a disaster-recovery plan, against threats both external and closer to home. And it doesn't always have to be deeply technical: problems with rogue executives are mostly resolved by way of a few legal procedures, rather than massive investment in complicated firewalls or network traffic and security-scanning systems.

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JON HONEYBALL

"I probably should have downed my pint and run, but he's a good mate and it would have been rude"

Jon explains what you need to know about Wi-Fi standards before buying a new router, and rescues his 15-year-old printer with a £50 part

I t was one of those conversations that started going down the rabbit hole remarkably quickly. While propping up the bar with a pint, my friend was asking me why his new Wi-Fi installation wasn't any faster than the previous one.

I probably should have downed my pint and run, but he's a good mate and it would have been rude. After all, he was in the process of buying me another beer.

What, I asked, had happened? He had decided that he wasn't happy with the speed of his ISP-supplied router, which had built in Wi-Fi, and so had gone and bought a shiny new Wi-Fi unit. It's a mesh design from a well-known vendor, but he had bought one unit to get started with. He could always add more if the radio signal reach wasn't enough. The ISP-supplied router had done pretty good service across his semi-detached house, so it was unlikely that more mesh units would be needed.

He's not technically illiterate and had managed to set up everything, including disabling the Wi-Fi in the ISP router. But he was still insistent that things were no better.

And this clearly wasn't right, because the new Wi-Fi unit was claiming "up to 10.8Gbits/sec Wi-Fi speeds". Deciding that yet more beer was required, I borrowed a pad of A4 paper and pen from the bar, and we sat down to go through the fundamentals.

First, let's deal with frequency bands. There are two in common use, with the third coming on stream now. There's a band of space in the

2.4GHz range, and another in the 5GHz range. Finally, there's the new 6GHz band, but that isn't used by many devices at present.

The first thing to realise is that both are unregulated spaces. You can do what you want in those two bands. Fortunately, most of the traffic is for Wi-Fi (the various 802.11 standards), which are reasonably strong signals, and for Bluetooth, which is a much weaker signal. How they can coexist is down to the way the signals work, and we will come back to this another time.

There's very little Bluetooth on 5GHz, with a new arrival being the connection between Apple's second-generation AirPods Pro 2 (USB version) and the forthcoming Vision Pro headset.

However, despite it being a wholly unregulated space, there are some standards involved, which is why products know how to talk to each other. Well, there's one exception: the DFS space in the 5GHz range, which overlaps with some radar functionality. But that's unlikely to be an issue for indoor operation.

Now let's deal with some fundamentals of radio. A stronger signal is better than a weaker one. If you're within a

few metres of a Wi-Fi base station, then your laptop or phone is probably receiving a Wi-Fi signal around -35dBm. That's a strong signal, despite it having a minus value. The noise floor is probably down around -90dBm, depending on how you measure it (devices have their own built-in noise floor). As you move away from the Wi-Fi base, the signal level drops, usually following the inverse square rule. And pesky items such as walls and doors attenuate the signal even further. This is especially true on the 5GHz and 6GHz bands, where the wavelength is shorter and suffers more from things in the way.

In my house, going two rooms away horizontally across the ground floor attenuates the 5GHz signal by around 25dB. Meaning our signal level of -35dBm is now -60dBm, and hence much closer to the noise floor. Such a signal level drop increases the error rate on the transmission, and more retries and resends are required. This slows down the data rate of the transmission – fortunately this is all built into the Wi-Fi standard, because it was known that you were not going to be within a few metres of the base station all the time. And if you were, it would probably be possible to plug your laptop in directly to the wired Ethernet.

The next thing to consider is the width of the connection. On 2.4GHz, this is typically 20MHz or 40MHz wide. It sounds a lot, but it isn't really. On 5GHz, we have more space to play with, which is why it has been 20MHz, 40MHz or 80MHz wide. The arrival of the 802.11ax standard allowed this to be 160MHz

BELOW Apple's new AirPods Pro 2 connect to the Vision Pro over 5GHz Bluetooth

A BRIEF HISTORY OF WIRELESS STANDARDS				
Name	**802.11 standard**	**Introduced**	**Frequencies**	**Max speed**
N/A	802.11a	1999	5GHz	54Mbits/sec
N/A	802.11b	1999	2.4GHz	11Mbits/sec
N/A	802.11g	2003	2.4GHz	54Mbits/sec
Wi-Fi 4	802.11n	2008	2.4GHz, 5GHz	300Mbits/sec
Wi-Fi 5	802.11ac	2014	2.4GHz, 5GHz	400Mbits/sec
Wi-Fi 6	802.11ax	2019	2.4GHz, 5GHz	9.6Gbits/sec
Wi-Fi 6E	802.11ax	2020	2.4GHz, 5GHz, 6GHz	9.6Gbits/sec
Wi-Fi 7	802.11be	2023	2.4GHz, 5GHz, 6GHz	46Gbits/sec

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wide, with 320MHz coming in the Wi-Fi 7 (802.11be) specification.

The connection width matters, in just the same way as a bigger pipe can carry more water. This is one reason why 5GHz connections can carry more data per second than a 2.4GHz connection. With the right equipment, an 80MHz pipe is double the width of a 2.4GHz 40MHz pipe, and a 5GHz 160MHz pipe is double that again.

Now let's consider the encoded signal. Back in the early days of Wi-Fi, we had the 802.11b standard (let's call it B for simplicity). This was superseded by the 802.11g version, and then the 802.11n standard, which was the first to be widely deployed on both 2.4GHz and 5GHz radios. In the days of B and G, which were 2.4GHz only, there was a dedicated 5GHz standard called 802.11a.

A big change came with the 802.11ac standard, which was faster still. Although mostly deployed on devices on only the 5GHz band, there are devices that support AC on the 2.4GHz band, too.

Before going further, we need to remind ourselves that the signal level of the radio is still the same. The bandwidth is increasing, but not massively, while the potential throughput is jumping up through the roof. That's because of the encoding capabilities of each standard. The 802.11 committee basically came up with better ways of encoding the data, and using other new technologies to improve the speed of the connection.

And then along comes 802.11ax – again on 2.4GHz and 5GHz, but now with the 6E channels on 6GHz as well.

Let's put some numbers to the throughputs. Here things can get a bit complicated. You and I think in terms of (mega) bytes of data when dealing with files – photos, music files, Word documents and so on. However, networking technology thinks in terms of bits, because it isn't really a "thing" you're sending, but a continuous stream of "stuff".

There are eight bits in a byte, so the easy, if slightly sloppy, rule of thumb is to use 10x to convert between bits and bytes, so 100Mbits/sec of user data means 10Mbytes/sec.

Now obviously bits are bigger numbers than bytes, and so the

marketing teams prefer them, too. They also like to claim that you magically sum all the available radio connections to get an even bigger and more impressive number. A reasonably high-end Wi-Fi unit will have one radio for 2.4GHz, one for the lower 5GHz band and one for the higher 5GHz band, too. And maybe yet another for the 6GHz band, if it supports 6E. So the marketing team likes to add A+B+C+D to get a huge marketing headline figure. This is what had confused my friend.

What sort of speeds can you really get? Let's assume that you have a clear radio space, without neighbours crowding the radio space. And that the device you're testing is the only device running. So, we have ideal conditions. Most modern AX laptops or phones will do 200Mbits/sec on the 2.4GHz band. There's a new generation that will go all the way to 400Mbits/sec on 2.4GHz. Most older laptops that do AC only do AC on the 5GHz band, and rely on the even older N specification on the 2.4GHz band where the maximum user data throughput is either around 100Mbits/sec or even 50Mbits/sec.
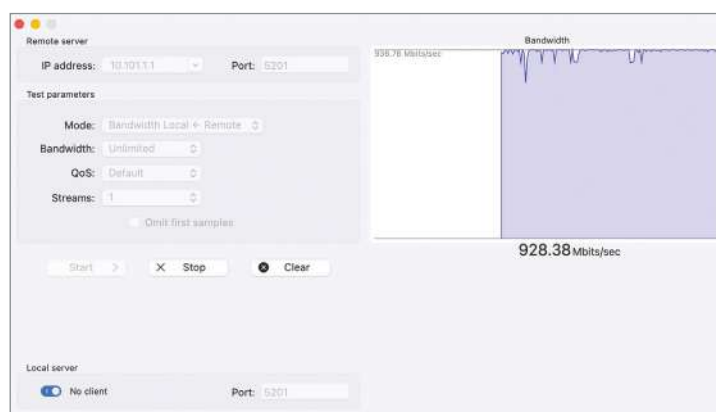
ABOVE *PC Pro* reviewed the Eero 7, our first Wi-Fi 7 router, last month (*see issue 352, p68*)

> **"The easy, if sloppy, rule of thumb is to use 10x to convert between bits and bytes"**

BELOW A 1GbE port maxes out at less than 950Mbits/sec, as shown in this iPerf test

Let's now look at the 5GHz space. A well-designed AC laptop on 5GHz can do around 800Mbits/sec, which is quite a speed. With AX, there is a big "it depends". And here we have to consider the onward chain and what you're connecting to.

A gigabit Ethernet cable (1GbE) will run to around 950Mbits/sec of user data. Now AX on 5GHz, especially with the widest pipe of 160MHz, will go faster than that, reaching speeds of up to around 1.8Gbits/sec of user data. But where is this data going to go?

If the Wi-Fi unit has a 1GbE port to the local network, then your super-fast Wi-Fi speed is going to be throttled to the 1Gbit speed. That's why higher-end AX Wi-Fi devices have Ethernet ports that run faster than 1GbE, to remove that bottleneck. Typically, this will be 2.5GbE, but some are running at 10GbE.

Problem solved, you think? Well, no. What's plugged into that 2.5GbE port? Let's say it's a local network-attached storage box. Does it have a 2.5GbE port on it? If it doesn't and it's only 1GbE, then all we've done is moved the bottleneck down the chain to the next device. If it does have a 2.5GbE port, you might think

everything is fine – but does the NAS have the horsepower and fast disks to actually deliver more than 1Gb of data onto the 2.5GbE connection?

We must consider the first bottleneck in the chain, too: your laptop or phone. It might well support the AX protocol, and thus you'd expect it to run to the heady heights of 1.7Gbits/sec. But many vendors are reining in the connection between the main bus to the Wi-Fi subsystem in the laptop so it runs no faster than 1Gbit/sec. For example, it's only on the most recent MacBook Pros that Apple has pushed the AX speeds beyond 1Gbit/sec, and the same applies to iPhones.

At this point, it's obvious that you must consider the whole chain, from the source device (laptop, say) all the way through to the server, wherever that might be. Let's say you're connecting to the internet – just how fast is your connection? An ADSL line will typically top out at 80Mbits/sec for downloads and 20Mbits/sec for uploads. That's an awful lot slower than the 1Gbit/sec bottleneck we've just been describing.

Let's say you've upgraded to fibre to the premises. That can run to near 1Gbit/sec speeds; I have such a connection from Openreach. Problem solved, we think: we now have a 1Gbit/sec connection on our AX Wi-Fi through the router, out to the internet. Well, maybe: public-facing servers on the internet often throttle their individual connections to save on bandwidth costs. So you might have a 1Gbit/sec connection to that server in the cloud, but the server limits you to 300Mbits/sec.

We're about to start getting the marketing push for the new Wi-Fi 7 802.11be devices, which are even faster with up to 320MHz channel width, and the possibility to parallel up the 2.4GHz, 5GHz and 6GHz radio to make a hugely fast connection. It will, of course, require a client laptop or phone device that not only supports Wi-Fi 7 standard, but also can join up all the radios into one unified connection. It will be worth looking at the vendor claims carefully when this arrives.

But will we need it? The answer is yes and no. We don't need AX speed, let alone Wi-Fi 7 speed. What we do need is their significantly improved

capabilities for handling multiple simultaneous connections, which makes for a better experience for all users on that Wi-Fi connection. That's where the benefit really arises, when you're trying to divide the throughput cake up for multiple hungry users.

Back to the pub, where we were staring down at the bottom of the glass. My friend realised now that his super-shiny new Wi-Fi router would be faster with his AX laptop than the older AC ISP supplied router. But he had nothing fast to connect it to, and certainly nothing that would support 2.5GbE from the Wi-Fi unit to the server. His internet connection, though fibre, doesn't run to the heady heights of 1Gbit/sec throughput. So his spend and upgrade was probably a waste of money. There was only one thing left to do: buy him another pint.

A £50 rescue for a 15-year-old printer

Despite buying lots of shiny new things, I keep my core devices for a very long time. A good example of this is my trusty HP Color LaserJet 5550. It's quite a monster: A3 double sided, five paper trays, and it stands chest height to me. I bought it 15 or so years ago, and it

has just worked. It has expensive taste in toner cartridges: a full set of four runs to nearly a grand, although they last for around 13,000 pages, and there are third-party options available.

It's been almost 100% reliable, but last week it threw a wobbly. The gear train in the first, upper drawer section came adrift and there was no way it was repairable. Since the paper path from the other paper trays goes up through the front of this drawer, it rendered the whole printer inoperable. A quick search of a well-known auction site located a used replacement paper tray. It arrived two days later, and the printer was back up and running. Total cost was around 50 notes, delivered. Not bad for a 15-year-old printer that was nearly five grand new.

Counselling the council

It was one of those tweets that demanded immediate application of More Beer. It seems that the Reading Council planning website was having some problems, and this had been going on for some weeks. It wasn't possible to log in to look at applications that were on public record.

It was raised on X/Twitter, and the official Reading Council feed responded with this:

"If you are still having these problems, you may need to go to 'Chrome – Settings – Security' and uncheck 'Always use HTTPS setting' once completed, try accessing the planning portal. When you have finished accessing the planning portal, please revert this setting. Many thanks."

In other words, the HTTPS connection to this service had broken. This could have been due

to a configuration change, or possibly a certificate expiry. Reading Council's recommended solution was to go into your browser, in this case Chrome, and disable the setting that forces the browser to use HTTPS. That way the connection could be made over HTTP. And, as the tweet then says, go back in and re-enable the "Always use HTTPS" setting when you have finished browsing the planning applications.

It's hard to know where to start with this. While I am willing to accept that it's unlikely there would be a man-in-the-middle attack on your session, delivering you the plans to Buckingham Palace instead of your intended 33 Acacia Drive, it does open up a whole set of questions about the competency of the IT service function running this server. If this server could fall off its HTTPS perch, then maybe the same could happen to servers handling much more personal and business-critical data that you might be submitting to Reading Council. I can't blame the council's social media team for repeating what it had been told, but I can certainly criticise the upstream process for failing to be on top of this.

Certificate handling is something that even the biggest players get wrong. But they tend to fix it within a few hours. Reading Council should have done the same.

Tunnel of love

You know how much I love VPN tunnels. It's much better than opening up ports on your firewall for incoming connections. So the question is: how quick is it? Now the house and lab are split, but both are on 1Gbit/sec internet connections, it was time to do some speed tests using OpenVPN clients and servers. The answer was surprising: a consistent 60Mbits/sec. So there's a lot of overhead to consider here. I'm looking at other protocols and will report back soon, because 6% throughput seems rather low, although it seems to be backed up by the literature. I have Wireguard on the list, which is claimed to be quicker. 60Mbits/sec is enough for what I actually need in terms of remote access to the core lab network, but more is always better. Obviously.

jon@jonhoneyball.com

LEE GRANT

"I've recently had a brush with greatness. A repair professional came to work in our shop"

With glass shards protruding from his hand, Lee genuflects in the presence of a genuine repair professional and does some California Dreaming

I'm not wishing our time away, but let's fast forward through time and re-emerge on 1 July 2024. This is the date when California's Right to Repair (R2R) bill (known as SB244) will become enforceable law, and I'm very keen to see how it will affect my repair business.

I'll save the finer points of SB244 for another time, but the bits that are important to us all as consumers and/or tinkerers is that the bill mandates that elements that manufacturers use to facilitate their own in-house repairs – such as parts, tools, documentation and software – must be made available. This is broadly what New York's R2R law promised, but SB244 adds timescales stating that products costing $50 to $99.99 must have repair elements available for three years after the manufacturer stops making the product. This increases to seven years for products costing over $100, which should make it easier to get things fixed.

As with any R2R legislation – and SB244 is arguably the most progressive R2R law around – it's far from perfect. Not all electronic devices are included, but most of the tech showcased within this wonderful magazine will fall beneath its jurisdiction. A couple of negatives are that it excludes games consoles (because of

Lee Grant and his wife have run a repair shop in West Yorkshire for over 20 years
X @userfriendlypc

> **"He said we had a nice shop. Flattery like this will get you the kettle switched on"**

BELOW Consoles are excluded from California's R2R bill

concerns regarding piracy) and it's not quite clear yet if all the tools will be available to the public. The bill, which you can read at your leisure at **tinyurl.com/353sb244**, refers to professional repairers, so I'm curious to see what credentials Californian repairers will need to present to get their SB244 seal of approval. In the UK, we don't have recognised accreditation for professional tech repair except at a manufacturer level, and I'm delighted to say that I've recently had a brush with greatness. A repair professional came to work in our shop.

A terminal problem

A laptop returned to our shop with a motherboard that had gone ping. Our customer was decent about it despite it only being sold a few months earlier. The premature demise of a major component isn't good for our customer, our business or the blood pressure. Thankfully, the machine was still within the manufacturer's warranty period, so we could spring into conciliatory customer service mode and handle the entire process while the client vanished on a conveniently scheduled holiday.

The machine had an on-site warranty, which is a rarity for machines in consumer land but speeds up the repair process considerably. Telephone support concurred that our diagnosis was probably correct and they were happy to ship a replacement motherboard directly to the shop. I don't mind admitting to the enormous pride in knowing that a global manufacturer not only trusted my diagnosis, but was confident that I could replace the part. We'll gloss over the bit where I'm saving said manufacturer a fortune by doing its work for nothing, but it was a sacrifice I was willing to make for us to progress down the path of

repairability together, as equals. Predictably, a dog with an upset stomach had also crossed this path and the manufacturer humiliated me into scraping my metaphorical instep on the grass verge of vanity. It forbade me from touching the spare part. The manufacturer would send a professional to our shop to complete the work.

One of the many tired tropes that lobbyists throw at the decision makers about R2R is that it's unsafe. This can be true, but so is crossing the road, and this argument is usually followed by another: that independent repairers are untrustworthy, and only official and approved repair agents are worthy of taking a screwdriver to your gadgets. This is definitely true.

Independent repair techs are nothing more than opportunist criminals, who live in the hope that machines comes into their expensive-to-run shops so they can upload your photos to the web the moment you're out of the door. It's our sole purpose for existen… what? Oh! Apologies. Our lawyers have asked me to clarify that I'm referring to an incident when a lady had her phone repaired by Apple (**tinyurl.com**/**353apple**), not an independent repairer. My apologies for making it seem like non-official repairers are second-rate, untrustworthy, charlatans hell-bent on ripping you off, rather than independent businesses who'll bend over to do their very best for you.

The professional arrived. He said we had a nice shop (thank you) and he'd never been in a proper repair shop before. Flattery like this will get you the kettle switched on. I'd cleared a bench for him to work his authorised magic and made polite conversation from afar while deliberately not hanging over him, grinding my teeth.

Around 20 minutes in, he emitted a pained yelp. The manufacturer had shipped the new motherboard expecting the CMOS battery from the broken machine to be reused. A tick in the sustainability box, but the professional tech had fumbled the battery removal, stripping the wires from the connecting jack plug. He held the broken wires in his hands and said: "I haven't got another. What shall I do now?"

Who am I to give my uneducated opinion to a professional? Should I

ABOVE Who would you trust to carry out an iPhone repair job?

keep my agreement with the manufacturer and let it spend more money dispatching a second professional to fit the part, or should I intervene? What would you have done? Of course, I helped. He was a fixer, like me and probably like you. While I don't have his certificates, I have many more bruises accrued from times when repair unexpectedly punched me in the jaw. I grabbed tweezers and a multimeter and showed him how to re-assemble the battery and test that the voltage was coming through. It was a simple repair for me, but a fresh experience for him. However, he now has that bit of knowledge too and maybe one day he'll pass it on and show someone else. R2R needs skills to be shared.

Within the hour, he'd got it wrapped up. The machine started and asked for the BitLocker decryption code. The professional looked at me expectantly, but the person who had it was lying on a beach somewhere, utterly, but critically, unaware of what BitLocker was. This is Windows Device Encryption (WDE), which I mentioned a few issues ago and springs into life on most modern

> **"It was a simple repair for me, but a fresh experience for him"**

BELOW Dell's website has some good advice on BitLocker recovery key prompting

machines when a Microsoft account is used at login.

Once again, Professional Tech Person looked worried. In his normal arena of business tech, either the IT manager has the code or the machine is reset, losing the data. In the consumer arena, losing client data is a heinous crime, standing shoulder to shoulder with the other major felony of not recovering a client's data after they've already lost it. As the Edinburgh philosopher Mark Renton once said, "It's a tightrope, Spud. It's a f*****g tightrope."

I let him scratch his head for a moment before telling him he was free to go. The professional had transplanted the motherboard and the amateur would finish up. It's easy enough to unearth a BitLocker code (**tinyurl.com**/**353locker**) once you know where to look, but when dealing with a fresh motherboard, be sure to rinse out the TPM, otherwise you'll be asked for the unwieldy string of digits during every boot. If this sounds familiar, Dell has a nice tech note (**tinyurl.com**/**353dell**) that you may find useful.

The Professional Tech Person was a great guy. He was young and keen, with a fabulous attitude, but he admitted that being a professional for a manufacturer means he doesn't have to worry about breaking things. He's got access to endless parts. Sure, he may get a kick from someone up the chain, but ultimately, if the client is happy, then all is well with the world. Interestingly, he told me the price of the replacement board: £570. Price that the customer paid me for the laptop in the first place: £550.

Reader's Drives goes wrong

This handily brings me to a key target in the next battle for the R2R movement: the pricing of spare parts. Luckily, this customer was under warranty, so the manufacturer was on the hook because no-one in their right mind was paying £570 for a part to fix a laptop that retailed at £550. One has to imagine that the profit on the £570
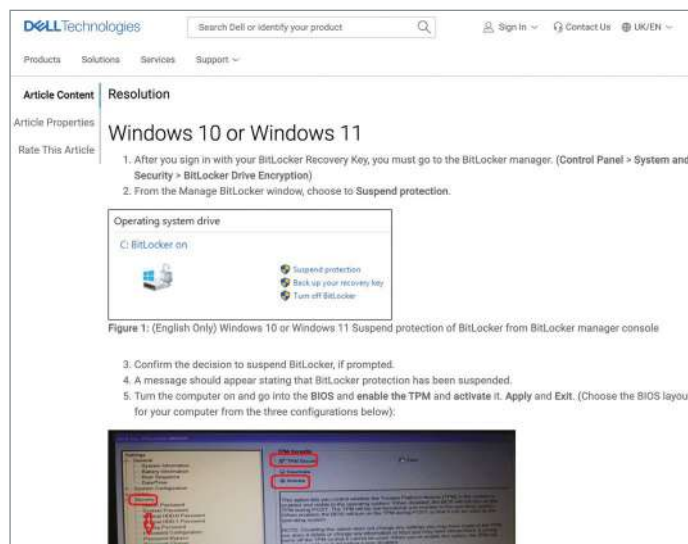
part is obscenely huge, as the alternative is that the manufacturer is selling all laptops at a howling loss.

Laptops don't have natural companion products (ink cartridges or app store purchases) to offset a loss leader, which is something to ponder as they greenwash about planting forests to offset carbon emissions while corporate strategy remains nailed to selling new products, abandoning stewardship of the lifecycle of current output.

Some laptop manufacturers have made noises about making parts available. Recently, I mentioned that Lenovo had made some decent inroads (*see issue 347, p115*), so I was slightly optimistic about repair success when one of its broken laptops, belonging to the son of a *PC Pro* reader, arrived in our shop.

The machine was a nice Lenovo Yoga 7 with a Ryzen 7 CPU, 16GB of DDR5 RAM and a 1TB SSD. It had been bought to get its owner through several years of gruelling university study without causing technical headaches. About ten days before freshers' week, the machine sustained a cracked screen while in the hands of its owner, which ruled out a warranty repair straight away.

At the time, Lenovo had zero availability of a replacement part, so I would need to source elsewhere, but here is where the ambition of Right to Repair legislators is being twisted. Theoretically, Lenovo can claim compliance by listing a part to replace this broken screen, but what it's advertising is a complete screen bundle, including the screen, digitiser, webcam, wiring, hinges and lid. It's like trying to replace the exhaust on your car and being forced to buy the engine that they bolted the exhaust to.

Much later, I discovered that the price of this screen bundle was £521.72, which is over 60% of the machine's original RRP of £850. This is also the same part price you'd have to pay if the webcam failed. Was there a better way?

Once the laptop was on the bench, I began the battle to extract the broken screen from the machine. The screen bundle is a composite of parts that were assembled and therefore can be disassembled. This screen was held in with three full-length glue strips, of which two snapped, forcing the extraction to be completed using a blend of heat and unsavoury language.

Most laptop panels have a narrow binding affixed around the circumference to ensure that the various layers stay together. Not this one. Removing this panel was akin to putting your hand into a high-speed blender filled with razor blades, resulting in many cuts and a good hour of removing glass shards from my hands with tweezers. Perhaps Lenovo's reason for selling the screen bundle is its fear of the mortality rate caused by removing shoddily made panels.

I sent the part information from the back of the panel to my screen suppliers, and only one of them said it could get the screen. The price to the customer (including fitting and adequate medical insurance) would be £315, which is still an eye-watering figure to replace a broken screen. The package arrived three weeks later and, as I unwrapped it, I counted the differences between what I had in my hand and the original panel. Note that this was meant to be an identical panel, so this figure should have been zero.

The obvious difference was that the fixing mounts were wrong, but as I had a young lad already waiting three weeks for his laptop, I was content to debond these and swap them with the originals. Here's a free *PC Pro* tip if you're ever swapping screens. Always test the panel before remounting, so you don't glue in something with dead pixels. This replacement screen was good as the same manufacturer

"Removing the panel was akin to putting your hand into a high-speed blender"

made it, the display was sharp and vibrant, while the digitiser functioned in all the right places.

I laid the screen into position and increased the difference counter by another point. This screen isn't rectangular but curved in the corners and around the webcam, and is genuinely a beautiful piece of engineering. These perfectly chamfered edges abut against an imperceptible plastic collar to create a seamless finish around the edges of the screen. Well, that's what was meant to happen. The replacement screen, for reasons that I'm still too infuriated to hear, uses a different radius cut on its curves, resulting in a gap of less than 1mm in places. In short, the screen didn't fit. And there were no other available parts. And the job had already taken too long. And my customer had waited three weeks for absolutely nothing. And there's nothing I could do about it. And this is why we need a proper Right to Repair to give easy access to sensibly priced parts.

The customer was utterly charming and thoroughly understanding, but that's *PC Pro* readers for you. My advice was to ship it back to Lenovo, who assessed the unit, but it took them 14 days to source and fit the part. They charged the customer a breathtaking £475 for the repair job – considerably cheaper than Lenovo was selling the part on its website. How interesting…

lee@inspirationcomputers.com

OLIVIA WHITCROFT

"There is debate over the extent to which the law addresses the risks arising from the use of AI"

Where do *Quantum Leap* and the law meet? Right here in this column, as Olivia explains the legal ramifications of using AI

I wanted to test the accuracy of ChatGPT, so I asked it a question about something I know a lot about. No, not the law, but the best TV programme ever: *Quantum Leap.* The show follows formidable physicist Dr Sam Beckett, leaping through time and putting right what once went wrong. I posed a question to ChatGPT about Ziggy, *Quantum Leap*'s AI with an ego, and ChatGPT informed me: "Ziggy is the AI system created by Dr Beckett's friend and colleague, Admiral Al Calavicci." No, she isn't! I corrected ChatGPT: in fact, Sam created Ziggy.

I worry greatly about *Quantum Leap* misinformation, but I realise the consequences for society of this error are minimal. How about if I were relying on AI to conduct legal research, review contracts or to decide how to advise my clients? Earlier this year, it was reported that New York lawyers had used ChatGPT for case research and submitted fictitious cases to the court in relation to a personal injury claim. The lawyers involved were subsequently fined.

And aside from use by lawyers, how about AI used for autonomous vehicles, healthcare services or to identify criminals? The consequences of an error may be even more severe.

Quality of output
While the use of AI for complex tasks can improve the accuracy and quality of outputs, there are also risks that outputs will be inaccurate, harmful, biased or unethical.

There are many recent examples. In October 2023, the UK Information Commissioner's Office issued Snap with a preliminary enforcement notice over the potential failure to properly assess the privacy risks posed by its generative AI chatbot "My AI", in particular for children.

Olivia is principal of the law firm OBEP, which specialises in technology contracts, IP and data protection
X @ObepOlivia

> "There are risks that outputs will be inaccurate, harmful, biased or unethical"

BELOW Snapchat could be required to stop processing data from My AI

In September 2023, it emerged that the Polish data protection authority was investigating a complaint made by a security and privacy researcher. He claimed that ChatGPT had generated inaccurate information about him, and OpenAI had failed to correct the errors upon request.

A month earlier, researchers from the UK and China published a paper in relation to pedestrian detection by driverless cars. The research found that systems were less accurate in detecting children compared to adults, and dark-skinned pedestrians compared to those with lighter skins.

Quality of input
Of course, the quality of the outputs of an AI system depends on the quality of the inputs. The *Quantum Leap* episode "Return of the Evil Leaper" features Alia, who seeks to counteract Sam's actions by putting wrong what once went right. Whenever Alia appears, Ziggy's calculations are put off track, as presumably Alia wasn't part of Ziggy's original training data.

If the training data has issues with quality, then the output is likely to carry the same issues. Training data may, for example, be inaccurate, biased or out-of-date, or may not take into account all factors relevant to the decisions the AI is making.

In 2018, reports revealed that Amazon had scrapped an AI recruiting tool that favoured men over women, the issue being that its training data was based largely on male applicants. There are many reports of facial recognition systems being less accurate at recognising black women than white men, having been trained on data sets primarily involving white men. The quality of database images can also be a factor, as some camera settings may be less effective at capturing darker skin tones.

In the recent complaint made to the Polish data protection regulator referred to above, the individual also claimed that OpenAI had failed to give him access to training data used to generate the allegedly inaccurate information about him.

Regulation – the EU approach
There is debate over the extent to which the law addresses, or should be created to address, the risks arising from the use of AI. The European Union has gone down the route of new regulation, with the EU AI Act currently going through the legislative procedure.

The EU AI Act classifies different AI models according to risk, and creates different obligations for each level of risk. AI systems creating an "unacceptable risk" are prohibited. This includes those that deploy subliminal techniques to distort people's behaviour and cause harm. AI systems creating a "high risk" include remote biometric identification, and those intended to be used as safety components of products or critical infrastructure. These are subject to a set of rules, including on risk management, data governance, transparency, human oversight, accuracy and security.

There are also transparency obligations for lower-risk AI systems that are intended to interact with people, such as chatbots, biometric categorisation and content-generating systems. Some AI systems that do not fall within any of these categories are deemed lower risk and will not be subject to the obligations.

Principles – the UK approach
In March 2023, the UK government published a white paper for consultation: "A pro-

innovation approach to AI regulation" (the UK AI White Paper). The consultation was open until 21 June 2023. At the time of writing, the results of the feedback have yet to be published.

To support AI innovation, the UK government intends to issue a set of five principles to be implemented by existing regulators. The paper refers to laws that can already address some of the risks posed by AI, including equality, data protection, human rights, product safety, competition, consumer rights and tort laws.

The proposed principles are: safety, security and robustness; appropriate transparency and explainability (including enabling understanding of how decisions are reached); fairness (including not undermining legal rights or discriminating unfairly); accountability and governance (including effective oversight); and contestability and redress.

In November 2023, the Artificial Intelligence (Regulation) Bill (a Private Members Bill) was introduced into the House of Lords. It seeks to establish an AI Authority to oversee other regulators' approach to AI (taking into account the principles), construct regulatory sandboxes, and require businesses to have an AI responsible officer. It also envisages transparency from those training AI, including giving users health warnings, and clarifying use of others' data and intellectual property.

Human oversight and contestability

AI systems use probabilities to decide what action to take. In *Quantum Leap*, Ziggy regularly calculated the odds that Sam was there to fix a particular problem, or that an action would result in particular consequences. In "Return of the Evil Leaper", Sam leapt into the Midnight Marauder, and Ziggy calculated overwhelming odds that Sam was going to be killed if he tried to stop some chicken races. Sam decided to scoff at the odds and try to stop the races.

Humans have the ability to exercise discretion and make their decisions beyond the AI system's probabilities. They may spot obvious errors or bias, or take into account wider ethical or moral concerns. Human oversight, and the ability to contest outcomes, may therefore be important safeguards for some of the AI risks discussed above.

Human oversight is one of the EU AI Act's rules for high-risk AI, which includes that a human shall "be able to

decide, in any particular situation, not to use the high-risk AI system or otherwise disregard, override or reverse the output of the high-risk AI system". Contestability and, linked to that, explainability, form part of the UK government's proposed principles in the UK AI White Paper. These aim to enable impacted parties to understand and contest harmful decisions or outcomes made by AI.

The UK GDPR already contains a prohibition on solely automated decision-making, meaning a decision made by a computer without meaningful human involvement. The restriction applies where the decision has legal effects for an individual or otherwise significantly affects them. This may include, for example, decisions about credit applications, recruitment, access to medical treatment or insurance premiums. There are exceptions to the rule, but the logic and consequences of the decision must be explained to the individual, and other safeguards must be in place, including the right to obtain human intervention and to contest the decision.

Under the UK Data Protection and Digital Information Bill (DPDI), which is still going through parliament as we go to press, the scope of the overall prohibition will be reduced, meaningthat many solely automated decisions will no longer be barred. During the consultation in 2022, concerns were expressed that the changes could have a disproportionately negative impact on people with protected characteristics, such as sex or race. An example was the claim that the 2020 A-level results algorithm produced different outcomes based on these characteristics. DPDI retains the same safeguards of human intervention and contestability, which seek to address some of these concerns.

Responsibilities

Organisations also need to consider who is legally responsible for AI-related harms, and how to manage these along an AI supply chain. In the UK, we need to look at existing laws to identify responsibility, such as controllers or processors under data

ABOVE An AI error in a driverless car could have serious consequences

> "Human oversight may be an important safeguard for some of the AI risks"

BELOW US TV show *Quantum Leap* has been rebooted for the 21st century

protection laws, and manufacturers under product safety laws. The EU AI Act allocates responsibilities between "providers" and "deployers"; a provider being a party that develops an AI system, and a deployer being a party using an AI system.

The UK AI White Paper recognises that AI supply chains can be complex and opaque, making risk management along the chain difficult. The paper suggests that assurance techniques and technical standards may assist with risk management, as part of its "Accountability and Governance" principle.

Contracts may assist to provide remedies along the supply chain. For example, if a business is deploying a new AI system developed by a technology company, the contract between the parties can allocate responsibilities between them. It may be that the business is providing some of the training data, in which case the technology company will not want to be liable for errors caused by low-quality data from the business.

Future risks?

I was delighted to watch the *Quantum Leap* reboot earlier this year. Though ChatGPT knew nothing about the reboot, as its last knowledge update was in 2021 (this was using GPT-3.5 rather than GPT-4). The reboot features a new leaper and a new Project *Quantum Leap* team, but still the same faithful AI, Ziggy. Or was she? Because – spoiler alert – as it turned out, Ziggy may well be the future mole allowing information to be leaked to Evil Leapers. Is this another potential AI risk to be addressed?

olivia.whitcroft@obep.uk

DAVEY WINDER

"As with dogs, this isn't just for Christmas. Any holiday weekends provide cybercrime potential"

The festive period is indeed the most wonderful time of the year, especially for cybercriminals. The answer: leave Scrooge-like out of office messages

As I write these words, Black Friday (soup maker and a pair of Superdry vegan hi-tops, if you must know) and Cyber Monday are fast approaching. I mention this because, while cybercriminals don't need an excuse to be cybercriming, the holiday season is correctly regarded as a prime-time threat.

Think about it: people are looking for bargains and stores are marketing them. Most of us are looking forward to some time off and winding down for just that. And delivery activity is ramping up, together with the number of missed parcel alerts. You've probably already started joining the threat dots here. Fraud shoots through the roof during such a time, especially when talking about an extended period from mid-November until the New Year.

The most immediate threat you think of is likely phishing, in all its guises. You aren't wrong. However, if you connect phishing campaigns with shopping activity, the knee-jerk reflex is to think it's a consumer-facing thing, and that's far from the whole story. Experience tells me that while consumers are the most targeted at this time of the year, corporate campaigns can be far more costly to businesses and lucrative to criminals.

Specifically, those spear-phishing campaigns are aimed at busy executives, while the more generalised but still targeted whaling ones try to hook victims further down the corporate food chain. This kind of targeted attack is becoming more prevalent, and for some crime groups, the only phishing weapon deployed because the potential for nefarious profit is very high indeed. Instead of being satisfied with a spray-and-pray operation – in the hope they can snag a credit card or two, swipe some
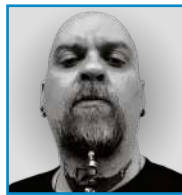
Davey is a journalist and consultant specialising in privacy and security issues
𝕏 @happygeek

"Corporate campaigns can be more costly to businesses and lucrative to criminals"

BELOW The National Cyber Security Centre issued a Black Friday warning to shoppers

banking details or maybe access a store account with some credit – taking aim at a corporate target holds the promise of network access and a route to ransomware riches.

The holiday season is highly favoured as it's a time when staff coverage will often be minimal, and those on duty perhaps less sharp than usual as minds wander to other things. The notion is that an initial breach during a holiday weekend will probably provide longer for the attackers to go undetected and for the incident response plan to kick into action. While access to credentials can be sought in many ways, and unpatched vulnerabilities remain a massively exploited weak spot, targeted phishing can be a relatively simple and successful method.

Of course, before the spear-phishing or whaling campaign can be executed, some research is required to ensure the right people are being targeted and in a manner likely to succeed. Addressing the latter first, shopping bait can be workable if aimed at a busy executive looking to grab gifts and groceries in a spare five minutes. Guards can come down courtesy of time pressure, leading to

mistakes being made that would be less likely at any other time of the year. As to finding the right target, you might imagine that social networks, especially business-oriented ones such as LinkedIn, would be top of the list, along with corporate "About us" pages. And it's true, both are veritable watering holes for fraudsters looking for personalising information. There's one avenue that I wager you haven't thought of, though: the humble out-of-office message.

As with dogs, this isn't just for Christmas. Any holiday weekends – be they Bank Holidays in the UK, Thanksgiving in the US or the various religious ones – provide prime cybercrime potential thanks to a combination of skeleton staffing and on-call responders partying with friends or family. For some organisations, especially at the smaller end of the business equation, there will be no staffing, no on-call anything, and the shutters will just go up for a few days. Whatever the scenario, it paints a tempting picture for the criminal-minded, assuming they can get enough information about opening times, staffing and response coverage. Which is where those out-of-office messages come in.

As far as I can tell, the only people who don't hate out-of-office auto-reply messages are criminals and whichever bright spark invented them in the first place. Oh yes, I'm going there: I'm plenty sad enough to have tried to find out. The best I can come up with, and get in touch if you know better, is Microsoft back in the days of Xenix email in the 1980s, which had an auto-reply feature command of Oof. Xenix transitioned to Exchange Server in 1993.

Anyway, back to the records. I'm one of those people who think that personal out-of-office messages for every member of staff are now redundant. A generic, "Sorry we're closed" version of the sign that hangs on shop doors is enough

Ian Thornton-Trump CD 🇵🇱 🇨🇦 🇬🇧 🏴 + 🇺🇦
@phat_hobbit

Replying to @happygeek and @Forbes

"Thanks for your email, I am away on leave for the holidays. My mobile number or as you threat actor like to call it the "SMS Auth" number can be found below in the event of emergency or if you want to SMISH and/or transfer my phone number to a number you control."

for those who don't already operate a 24-hour online business. No need to let everyone and their mother know that John Sparks is on holiday until 4 October and you should contact Jenny Pickles (insert contact details here) if it's urgent. And certainly please don't fall into the trap, which I have seen way too many times, of detailing some project you're working on and telling the email recipient that the aforementioned Jenny is briefed to deal with it in your absence.

You might be thinking that there's not a lot of actual harm, that the real-world threat from such a response is minimal. But that's not the case at all. Let's dissect this example from an attacker's viewpoint. As that potential attacker, I would have already researched LinkedIn to reveal employees at the target company. I send a carefully crafted email hoping they will take the bait and open the malicious attachment. Instead, I get an auto-response telling me that Jenny is dealing with a client project I previously knew nothing about.

This has made my life a lot easier as I now have a real, tangible hook to bait Jenny with. I now send her an email that has been spoofed to appear to be from the sales director, lead developer, account manager or whoever fits into the narrative best based on the information I have. That email also comes with a malicious attachment, which is now much more highly targeted and almost certain to get actioned upon.

There's more. Jenny's been briefed to deal with "me" in the absence of John, who has told her how important this client is and to deal with them promptly in his absence. Time-sensitive pressure adds to resource overload stress (Jenny still has her own clients to deal with, after all) and results in the document being opened and the malware that will let me access the target network executed.

So, what should a secure out-of-office communications strategy look like? Ideally, and I fully accept that the size of an organisation, the nature of the business, and the number of clients/projects undertaken will shape the actual process more than anything, you should do away with email auto-responses altogether. Instead, set up redirects so any incoming email gets forwarded to "Jenny" without revealing any of that precious social engineering data. Jenny can then deal with it normally, considering the standard security protections, without the cleverly leveraged pressure coming into play.

If you really must go down the auto-reply route, then ensure the information included is at the bare-minimum-required level. So, no direct contact numbers for named staff members; use the generic company or department number instead. Say you are away from the office and will get back to the sender as soon as possible without qualifying that absence with dates.

Perhaps most importantly, have a process in place at your organisation that securely covers workflow in absentia. That way, your colleagues will know who is most likely to contact them, their needs and, vitally, who is authorised to validate transactional requests.

What if a ransomware gang reported YOU to the authorities?

As much as it sounds like the pretext for a modern-day Monty Python sketch, one ransomware group has started to report victims to the authorities for not reporting they have been breached.

The highly prolific crime group ALPHV, or BlackCat if you prefer, has taken the rather bold step of doing precisely that. Changing the rules for how long organisations have to report a "material cybersecurity incident" to the Securities and Exchange Commission (SEC) in the US, giving them just four business days to do so, appears to have opened a ransom

ABOVE It's funny because it's true, or rather not funny…

"You've got to admire the chutzpah of these people if nothing else"

BELOW Royal Mail lost millions of pounds thanks to a LockBit attack in early 2023

payment leverage opportunity for the bad guys. In the first case of its kind as far as I'm aware, ALPHV reported a digital lending platform called MeridianLink to the SEC.

ALPHV said, on its media leak site, that it had reported this non-compliance as it was "involved in a material breach impacting customer data and operational information" that required formal disclosure. You've got to admire the chutzpah of these people if nothing else.

"Misuse of the new SEC rules to put additional pressure on publicly traded companies was foreseeable," Darren Williams, CEO and founder at BlackFog, said. "Moreover, ransomware actors will likely start filing complaints with other US and EU regulatory agencies when the victims fail to disclose a breach within the timeframe provided by law." I fear he might be right.

The cost of ransomware remediation gets real

I see no end of press releases, media reports (likely based on those press releases) and FUD flying around and throwing up huge numbers regarding the cost of a ransomware attack on an organisation. One, however, has hit home, as it doesn't involve the usual billion-dollar US-based megacorp such as MGM Resorts, which had a reported post-ransomware recovery cost of $110 million. Instead, it's the Royal Mail.

Remember when Royal Mail fell victim to LockBit way back in January 2023? Now, financial statements from parent group International Distributions Services (IDS) have confirmed just how much such an attack can cost. Although there wasn't a precise breakdown of how the cash was spent, rather being grouped under the somewhat vague umbrella category of remediation and resilience, the number itself is made clear: £10 million. This covers the six months from the incident discovery. IDS also disclosed

that its revenue dropped by 6.5% as a result, equating to approximately £22 million.

Figures like these must be considered when taking sides on the pay/never pay ransom debate. The decision isn't straightforward if the cost of not paying the ransom, including business disruption but ignoring any potential reputational damage, is twice the amount demanded. It should be, but it isn't because there can be industry-specific regulatory issues in play, you're trusting the word of criminals that they will delete your data and not sell it on, and even that the decryption key they supply will work.

Cyber insurance policies? These can both be a help and a hindrance in my view. From the help perspective, and again conscious of the differences between vendors and policies provided, these will usually require baseline security requirements to be firmly in place, which can help focus your mind on proactive prevention. The argument that having an insurance policy means you don't have to worry about preventing loss is moot regarding ransomware policies. Also, the most worthwhile cover will include using a reputable incident negotiation service to act on behalf of your organisation, and ultimately the insurer stumping up the ransom after all.

Finally, such a policy will likely cover the broader remediation costs for returning to your operational feet. Anyone who has worked in incident response will tell you that getting hold of a decryption key means little in getting everything back up and running. To do that requires a resource-heavy amount of data migration and rebuilding.

As for hindrance, the idea of the payment of ransoms providing resources for criminal actors to continue cramming, evolve, and get better at it holds firm. Having paid up once, you can also be seen as a promising target for future attacks from the same threat actors or others, as word spreads quickly enough when most ransomware groups these days rely upon affiliated parties to execute the initial compromises.

davey@happygeek.com

STEVE CASSIDY

"Apple seems to have decided that the home hacker isn't a good target for its ire"

How to use Hackintosh hacks to breathe fresh life into Mac Pros that date back to 2010, and why virtualisation isn't an option for these old machines

For my 2023 Christmas present, I settled on a ten-year-old graphics card. I'm certainly not a big gamer or 3d modeller, so the lack of megaflop processing around 2013 isn't a major concern. My interest is focused almost entirely on the thorny business of compatibility: in particular, which PC graphics cards can you put in your Mac?

Plenty of immediate and wrong answers are available. Some people say it's none, others say all, and a third group makes a lot of money by mastering a procedure that reflashes the card BIOS from the PC to the Mac version, for a rare and shrinking subset of the available stock of cards.

Because of the unique way in which Apple works, this isn't a straightforward discussion about technology. It's about hackers, legal retribution (or the lack of it), the international geopolitical impact of selective tech support, and karma. I am thinking in particular about the strange relationship between Apple and the globally distributed, fearsomely inventive cohort of techies responsible for the Hackintosh.

Don't think you know the Hackintosh story because (like me, I confess) you dipped into the field back in the noughties, made yourself a nice substitute for a Mac mini out of a Dell corporate-grade PC, and then left it running your iTunes library for the next decade or more. Things have changed.

There were several drawbacks to the whole idea, even during that first flowering. Most people interested in using PC hardware to run Apple apps and operating systems were into the concept because they had very expensive apps they wanted to preserve, without being obliged to spend

Steve is a consultant who specialises in networks, cloud, HR and upsetting the corporate apple cart
@stardotpro

"Mac Pros have an uncommonly persistent fan club, because they seem to live on forever"

what might be their life savings (I'm particularly thinking about those living in countries with smaller economies) to keep pace with the triad of hardware, OS and application updates delivered by the tech sector.

I know that there are other demographics who regard those costs as (to quote Mr Honeyball) "less than the office coffee budget", and that's fine and dandy for them. The problem at the time was that nobody really knew how Apple would react to the Hackintosh movement and other threats to its revenue stream. By this point, Apple was expected to have decimated the hackers for having the temerity to borrow its intellectual property. Fact is, it's not happened. While going after those who pose a direct commercial threat is one thing, Apple seems to have decided that the home hacker isn't a good target for its ire: an attitude that has paid back in the most incredible way.

I have here five Mac Pros. They are very old, dating from around 2010. One is my current main network services server; the other of the same age used to be my workstation, before its extreme age caused the fans to max out just trying to show an animated advert on a web page. Let's pass those by, because they're very early models, and focus on the other three: a set identified as MacPro5,1 systems (one is legalistically a MacPro4,1 that has been flash-upgraded, but I'll ignore that for a paragraph or two).
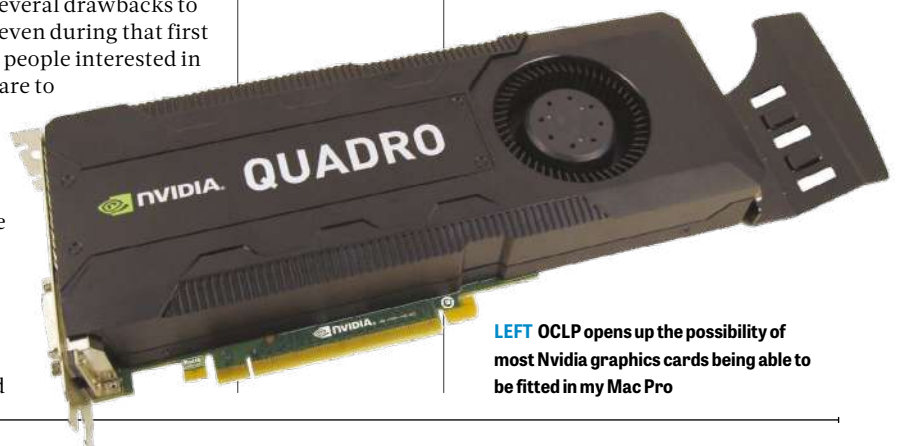
LEFT OCLP opens up the possibility of most Nvidia graphics cards being able to be fitted in my Mac Pro

Mac Pros have an uncommonly persistent fan club, because they seem to live on forever and are still supported by a wide range of hardware add-ons. In particular, NVMe storage cards, which would be absolutely fantastic due to their speed were it not for Apple characterising them as "removable storage" in OS X.

Enter the OCLP, standing for Open Core Legacy Patcher. Building on the work done over a couple of decades by the Hackintosh community to bridge the compatibility gap between Mac and PC hardware, the OCLP does the same thing between older Apple machines and the restrictive hardware support in newer Mac operating system releases. This has been so successful that there are products from mainstream hardware makers that would make no sense at all without the extended platform lifespan made possible by the OCLP.

The hack that makes NVMe drives look like internal disks, not removable keys, is one such gain. Nvidia has joined in, too – almost any of its

graphics cards can be put in my 5,1 revision Mac Pros; all I have to do is match the OS release on my boot disk with a "web driver" download from Nvidia. The next time I boot up, I'll have video drivers for the more common PC-compatible Nvidia cards. That saves me about £200 per machine, if I compare the vast pool of Nvidia cards on auction sites with the much smaller muddy gulch of unbusted Apple-specific cards on the market.

This grassroots movement to preserve the Mac Pro seems to be here to stay. Take, as one prime example, Sonnet's combined 10GbE, NVMe, USB-C and RAID cards: devices I would certainly consider buying at £400 to put in a Mac Pro that's valued at only £150 due to the massive speed and storage hike it confers. I expect to see similar kit coming out to extend the life of Macs, based on the solid contribution presented by the OCLP and various "patcher" utility releases.

The whole story tells us some important things about the shallowness of a short-term profit motive, and how

ABOVE Apple's Mac Pro is renowned for its longevity

LEFT Sonnet's combined 10GbE, NVMe, USB-C and RAID card is a winner

manufacturers can secure a good reputation with their customers and wider development communities. Rushing around stamping out hackers looks to be the worst possible strategy.

Just virtualise it!
I'm a big advocate for virtualisation, so you may wonder why I seem to have ruled it out as a strategy for software licence preservation on Apple machinery. Surely if it's plug-and-play on Windows and now Linux machines, there's a solution to the Apple problem using desktop virtualisation?

That would be a no. The core reason why Apple-based virtual machines haven't had the same acceptance as PC-based ones is that to make a working VM you have to use an Apple machine firmware chip. Either by taking a copy of it, or by running your Apple VMs on a hypervisor that's on an Apple computer. Taking a copy is straightforward theft of copyright (literally), and that means the market in VM hosting for Apple isn't ever going to develop specialist companies and service providers.

I have yet to see good evidence of Apple presenting any home enthusiast with a cease-and-desist order, but I have seen companies shut down after pushing their luck with Apple's products. Way back in the day there was a business that took a standard Mac SE/30 and ripped all the guts out, stuffed it into a laptop casing, and then charged handsomely above what was already one of the most

The international problem

The sheer determination of Hackintosh builders and coders is easier to understand once you give up on the helicopter perspective and take a view from yet further away; Low Earth Orbit is about right.

At this altitude you can see many countries at a single glance, and yet their borders become invisible. This is not the view taken by the sales departments of most businesses: they love a bit of territorial division. Whatever the driving force that separates nations (race, religion, language, economics), the reaction of the seasoned salesman is to seek to conquer by dividing, and Apple has been no exception to this rule.

That's why we find ourselves in 2024 with several countries actively denied official sources of either Apple hardware or Apple support. Sometimes this is about the country itself (those with poor or no adherence to copyright regulations, or with very small and risky economies) can find

RIGHT Corporations are fond of borders between nations

themselves denied the customer relationship standards that make Apple such a stand-out brand in the more developed world.

It's no surprise to find that countries without official Apple presences are home to lots of eager Hackintosh users and developers. If you can't get it the right way, but you want to use the software you learned while in college in the US, UK or most EU countries, then your choice is restrained through no fault of your own. Most of us are already reluctant to trot down to the Genius Bar with our MacBooks after they've been bent in half during a scooter crash – even though Apple's response to such a disaster is better than almost anyone else's in the industry – so just imagine what life must be like if that Genius Bar is several plane flights away.

Being able to get your support locally is a big deal. Having a local guy ready to make you a Lenovo or HP laptop Hackintosh is, for many potential Apple users, a big advantage where Apple has chosen not to tread.

expensive computers you could buy. The threat of legal action from Apple did for that company. So, my point is, while individuals might get away with hardware hacks, companies won't, and that is a big barrier when it comes to virtualisation.

The other big problem is that Apple backed the wrong horse when it comes to storage. I use iSCSI as my disk-access protocol, and found myself completely stunned to discover that, as standard, macOS X doesn't include it. Using abstracted, network-based storage is pretty much a cornerstone of virtualisation, be it server, cloud, desktop, PC, Mac or even Linux. There are some third-party software tools to make your Mac speak iSCSI – I've been using the iSCSI Initiator X by Kernsoft – but I might be disloyal and have a go with the Atto Xtend. If, that is, I can untangle the rules governing whether it works only with Atto's networking hardware, or with any old path to the company network.

The reason why iSCSI matters in virtualisation is all about the size of the VMs you create, and how many of them you want to be running at the same time. Big VMs are more the rule than the exception on the desktop, and copying them around from one physical location to another is a powerful disincentive to further experimentation. Apple felt that by using Fibre Channel it had an answer to the more general demand for terabytes.

An unexpected gem

One of the problems with virtualisation is that it produces completely divergent experiences, according to apparently random decisions that experienced nerds will make more or less on a whim. This is the "it should work" trap: in my case, my first time with the StarWind P2V/V2V utility gave all the classic signs of being unworkable.
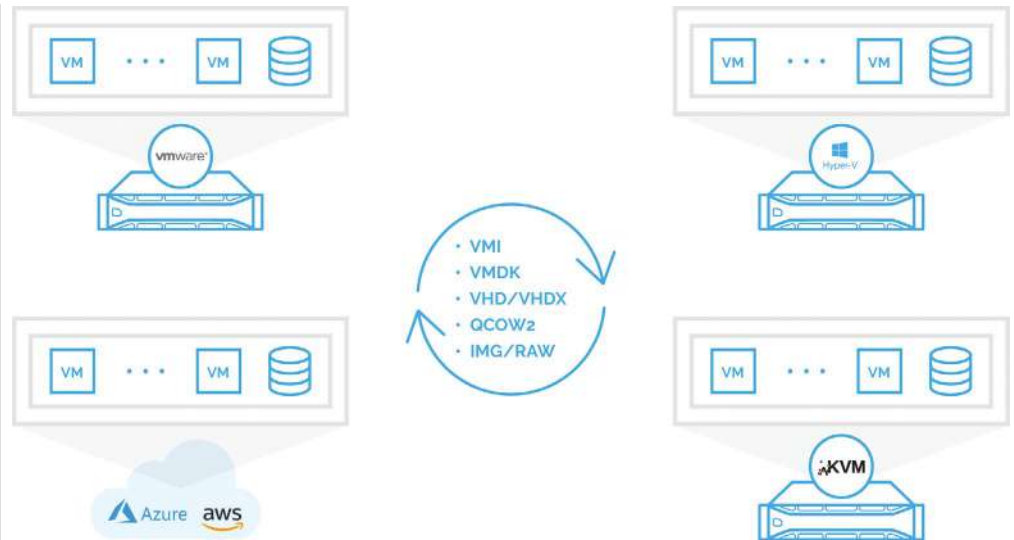
I grabbed a VM image written to a NAS share by Windows Server 2012 backup, dropped it on a Server 2019 Hyper-V host and pressed "Start". No luck: just a ticking plain-text cursor in the VM console screen. Some Googling later, I found the StarWind utility, and completely ignored the sage advice that it was free to use because support was only offered by joining the StarWind online forums.

Plunging in, I grabbed the backed-up VM image and pointed the conversion output target to my new 2019 server. This produced a different result to a dull physical file copy. I couldn't get the resulting "converted" machine to open a console window. So naturally, I threw a tantrum, didn't look in the support forum, and left the project for a few weeks, as if the passage of time would change the result.

In a way, it worked, because the next time I tried the process, I'd forgotten exactly what options I'd used on that first run. This time, I didn't grab the backed-up image: I stopped the VM and used the direct Hyper-V storage access connection method, which reads out of the Hyper-V service port on the 2012

ABOVE An overview of how StarWind works, but don't ignore the small print

> "The moral of the story is that doing your research is never a poor option"

BELOW You can use third-party tools to bring iSCSI to your Mac

server and deposits this into the updated services on the Hyper-V service in the new, 2019 vintage server. Initially this put up a pessimistic progress bar, making it look like coming back in the morning was the next milestone in this operation. Fortunately, I popped back to the office after dinner to discover a 100% complete process. What's more, the VM thus created on the new server was a hybrid of a 2012 RDP host with the integration services install suitable for 2019 as a Hyper-V host.

This try was a faultless process, allowing for the wonky progress bar and the peripheral annoyance that either instructions or meaningful error messages have been left out of the overall package. This is the way virtualisation seems to go: people will struggle to match their adventures with the results of their peers, who tried a different mix of components and paths through the labyrinth of configuration settings.

The moral of the story is that doing your research is never a poor option. If I'd stuck to that rule, I would have been paid two months earlier!

✉ cassidy@well.com
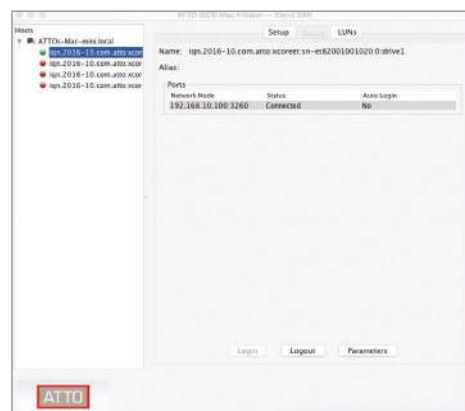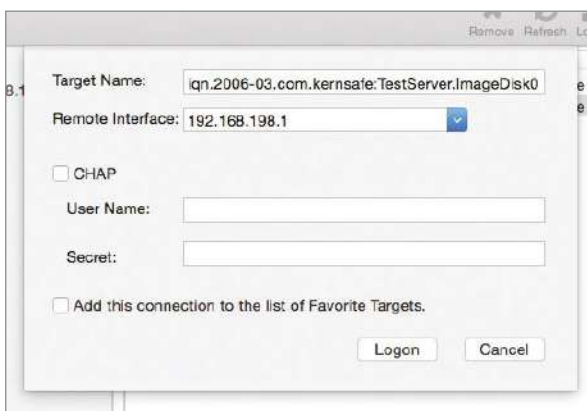
40 years of the Mac

Released in January 1984, the Apple Macintosh soon became an iconic machine, starting a range that continues to this day. David Crookes looks at how that first computer came to be

It was director Ridley Scott who introduced the idea of the Macintosh to the world. His iconic commercial, *1984*, written by Steve Hayden, Lee Clow and Brent Thomas, was quickly acclaimed as a masterpiece, representing the Mac as a revolutionary product that could save humanity from conformity.

With more than a nod to George Orwell's classic novel of the same name, and aired during a Super Bowl break on 22 January 1984, it made consumers sit up and take notice. Within 100 days, this $1 million, 60-second ad helped Apple sell 72,000 Macs. But even then, no-one could have foreseen how much of a blockbuster the Mac would become.

The computer had been in development for quite some time. In 1979, Jef Raskin, who had joined Apple the previous year as employee number 31, had proposed an easy-to-use 8-bit computer, codenamed Annie, that he envisaged could sell for just $500 if it was designed well enough and was manufactured in high volume.

To help him achieve his aim, he created a team that included software developer Bud Tribble, computer engineer Burrell Smith and student Bill Atkinson, who would also work as a computer engineer. He also wrote a mission document called the Book of Macintosh – a play on the Book of Mormon. Raskin later joked that the tome had an anti-religious overtone.

The book was a collection of essays that went into detail about what the Macintosh should be. It was intended, Raskin wrote in May 1979, to be a "computer designed for the Person In The Street". To that end it would be a machine "that will be truly pleasant to use, that will require the user to do nothing that will threaten his or her perverse delight in being able to say: 'I don't know the first thing about computers'." It was also going to be "one which will be profitable to sell, service and provide software for".

That essay, Design Considerations for an Anthropophilic Computer, clearly stated that users shouldn't have to worry about what was inside the machine. Since Raskin didn't want anyone to ever have a need to see the interior, he therefore proposed that every add-on would be a separate appliance – a standalone device with its own case, sold as a complete item.

"Seeing the guts is taboo," he added. "Things in sockets is taboo (unless to make servicing cheaper without imposing too large an initial cost). Billions of keys on the keyboard is taboo. Computerese is taboo. Large manuals, or many of them (large manuals are a sure sign of bad design) is taboo. Self-instructional programs are NOT taboo."

A preliminary cost investigation in September 1979 showed the level of Raskin's ambition. A computer with a 6502 CPU and 64KB memory should, he stated, cost $125 to build, making an on-sale

ABOVE The Apple Mac came with a keyboard and a one-button mouse

> **"Seeing the guts is taboo. Things in sockets is taboo. Computerese is taboo. Self-instructional programs are NOT taboo"**

BELOW The well-hidden Macintosh motherboard in all its glory

price of $500 feasible. He even believed it could go as low as $300 with increasing quantities. Such prices wouldn't include a display, disk drive or printer, however. These would need to be bought separately.

The following month, Raskin wrote about Steve Jobs, Apple's co-founder. He said Jobs had told him not to worry about price and to just specify the computer's abilities. "Starting with the abilities desired is nonsense," Raskin countered. "We must start with a price goal and a set of abilities and keep an eye on today's and the immediate future's technology."
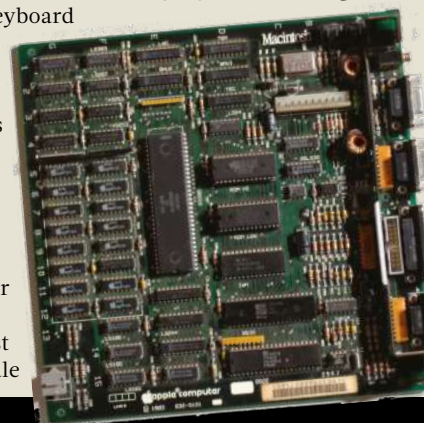
A good job

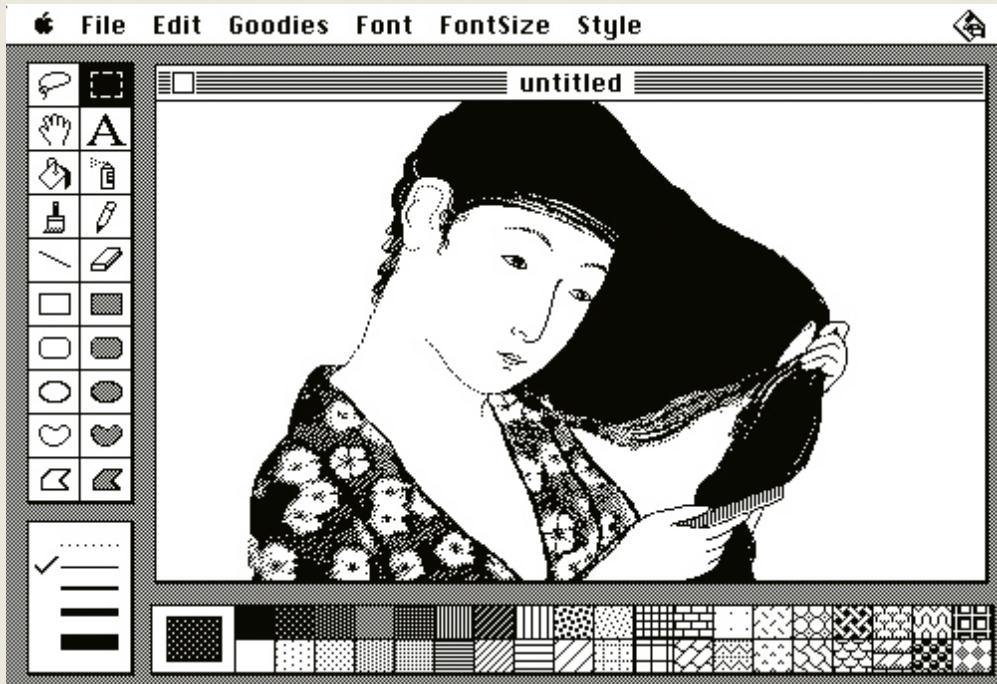Jobs wasn't part of the Macintosh team at this time. He was working on a desktop machine called Lisa. Development of this computer had begun in 1978 and it was very much a high-end affair – it ended up costing $9,995 when it launched in 1983, aimed at the business market.

For much of that time, Jobs had been hands-on. He worked on incorporating a similar mouse-driven GUI to the Xerox Alto and he was enthusiastic about the project. He strongly believed the Lisa would be a success thanks, in

File Edit Goodies Font FontSize Style

untitled

File Edit View Special

Mac System Software

3 items   227K in disk   173K available

Mac System Software

System Folder   Empty Folder

SysVersion

System Folder

5 items   211K in folder   173K available

Finder   System   Imagewriter   Note Pad File   Scrapbook File   Clipboard File

Trash

ABOVE MacPaint was developed by Bill Atkinson with an interface designed by Susan Kare

LEFT The System 1 GUI, which proved to be an instant hit
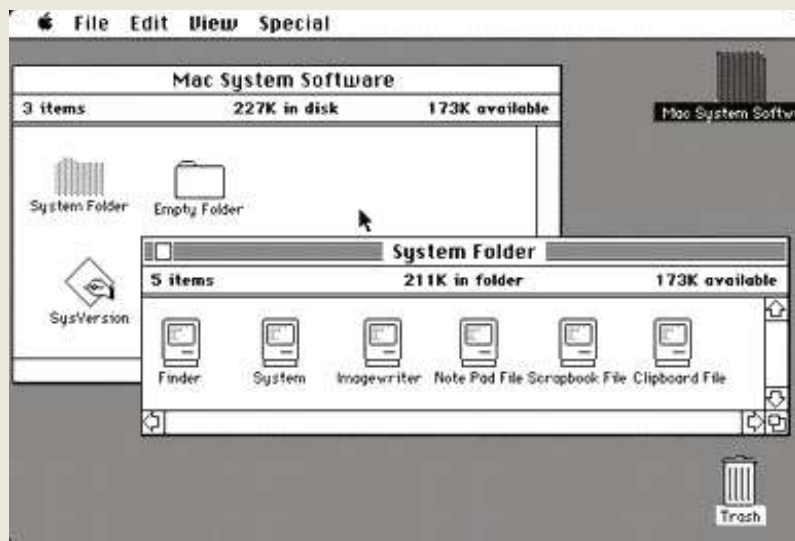
by 1980. Even so, he made the computer a far better product.

"I found it extremely easy to communicate with Burrell and part of that was that the turnaround time with Burrell for trying out new hardware ideas was like the turnaround time I was used to for trying out new software. He would do it overnight," said another member of the Macintosh design team, Bud Tribble, in a 1984 interview with *Byte* magazine.

"If I came up with an idea from the software standpoint and said to Burrell, 'wouldn't it be nice if we had this in the hardware?', he would come back the next day and say, 'we can do that if you make this slight change in the software'. In a very short time, we would get the whole thing going."

As if to demonstrate how hard Smith worked on the project, he designed five logic boards for the Macintosh. And, as time went by, more and more people joined the team. While it was still being treated as a sideline product by Apple, the hands-off approach by senior management seemed to work in the team's favour. They were able to work together in a small office and make their own decisions, producing a machine that ended up being very attractive to Apple.

■ Super system

Software was also very important. The Macintosh operating system, which became known as System 1, fell under the control of Hertzfeld, who also worked on the User Interface Toolbox, Windows Manager, Control Manager and Menu Managers. He says his first job on the team was to help verify that the disk controller was working properly, but the manner in which he ended up joining was unconventional.

"Steve came by my cubicle at Apple," he told the Land of Giants podcast, adding that a conversation ensued and he agreed to join the Macintosh team. Hertzfeld told Jobs he'd wrap up some documents and start on Monday. "He grabbed my Apple II off my desk and started walking away with it." Jobs had told him, "the Macintosh is the future of Apple. You're going to start on it now."

System 1 was groundbreaking. As well as having a GUI, it had features that would be part and parcel of Mac operating systems for years to come, among them Finder, overlapping windows, a clipboard, a Trash can, extras such as a calculator, control panel and clock, and a menu bar.

"The menu bar was a key feature that encouraged the user to discover, explore and access the range of commands available to them," Hertzfeld told *PC Pro*. "The original

part, to the Lisa OS, bundled software, a Motorola 68000 CPU running at 5MHz and 1MB of RAM – far in excess of many other machines at the time.

But Jobs' overbearing nature and meddling saw him being kicked off the project in 1981. He began to look around for something else to sink his teeth into and spied an opportunity with the Macintosh, duly taking over the hardware side of development and seeking to put his own stamp on it.

Raskin wasn't happy. It's said that Jobs eventually persuaded Apple's then CEO Michael Scott to allow him to lead the project. When Raskin left, he wrote an angry memo.

"While Mr Jobs's stated positions on management techniques are all quite noble and worthy, in practice he is a dreadful manager," Raskin said. "He is a prime example of a manager who takes the credit for his optimistic schedules and then blames the workers when deadlines are not met."

Even so, there's no denying that having Jobs on board was a positive move by Apple, no matter what motivated it. A decision had already been made to change the processor to the Motorola 68000 running at 8MHz, and the Macintosh was to add a black-and-white, 512 x 342 screen, a 3.5in floppy drive and double the memory to 128KB. Jobs brought a management style that encouraged those working on it to do the best they could.

■ Hard work

Burrell Smith was also an important part of the Macintosh's success. He'd been an Apple II service technician and he was recommended to Raskin after helping Atkinson add extra memory to the machine. Smith's ability to cut the number of chips while boosting performance was uncanny, although not quite enough to prevent the Macintosh from reaching a suggested price of $1,000

"While Mr Jobs's stated positions on management techniques are all quite noble... in practice he is a dreadful manager"

Macintosh was also the first affordable computer that was relatively easy to use, thanks to its breakthrough graphic user interface."

The OS and Macintosh went hand in hand. "Without the system software, the Macintosh wouldn't be the Macintosh – it wouldn't exist," Hertzfeld added. He also said it had an impact on the wider industry. "The original Macintosh was widely copied, especially by Microsoft, and it elevated the entire PC industry," he said.

Instrumental in getting the look right was Susan Kare, Hertzfeld's old school friend. She became the screen graphics and digital font designer and was originally given an Apple II in exchange. "I was introduced to the project by Macintosh system software legend Andy Hertzfeld who knew I was really interested in graphics," she told *PC Pro*.

"Andy recommended trying out some sample icons using graph paper, although after getting hired I transitioned immediately to an icon editor (written by Andy) that showed a 100% view and greatly enlarged view side-by-side."

Her work was varied. She decided to use scissors to symbolise a cut and she had an icon of a bin for the trash. Kare also created the iconic smiley face on a computer screen. She had no experience of creating computer graphics but she managed to work wonders in a 32 x 32 pixel square.

"I was influenced by all kinds of graphics, for example signage, folk art, needlepoint, mosaics (pseudo-digital techniques) and various symbol systems," she said. "As for my favourite, probably a tie between the smiling Mac and the watch."

How much?

All of this wrapped up into a winning machine. The Macintosh became known as the Mac in 1999. Colour had arrived in 1987, and Power Macintoshes heralded a move away from the Motorola 68000 series in the mid-1990s. But when it was released, the original Mac had blasted apart the value tag. It cost $2,495.

This disheartened the team. In an article written in 1993, Hertzfeld spoke of a price fight and a struggle to keep the Mac from jumping over the $1,500 price point. In the summer of 1983, he said, "we grudgingly accepted that the Macintosh would have to debut for $1,995", but CEO John Sculley was hired in April 1983 and the decision to market the Mac big time was not a cheap one.

Hertzfeld recalls the moment the high price was revealed. "Steve Jobs strode into the software area one evening, looking angry. 'You're not going to like this,' he told us, 'but

Making of a Mac   How the Macintosh appealed to consumers 40 years ago

Graphical user interface
The Mac's mouse-driven operating system made its debut along with Finder and Trash

Built-in monitor
The 9in black-and-white CRT monitor could display a one-bit graphical resolution of 512 x 342

Good venting
The Macintosh didn't need a noisy fan, instead using vents on the casing

The internals
A 32-bit Motorola 68000, 128KB of RAM and 64KB of ROM were good enough for graphics work

Floppy disks
Each side of the floppy disk could hold 400KB, and the OS ran from a floppy rather than a hard drive

Sculley is insisting that we charge $2,495 for the Mac instead of $1,995, and use the extra money for a bigger marketing budget. He figures that the early adopters will buy it no matter what the price. He also wants more of a cushion to protect Apple II sales. But don't worry, I'm not going to let him get away with it!'" As it happened, Jobs didn't have a choice.

On fire

Two days after the Mac advert aired during the Super Bowl, Jobs took to the stage to officially launch the Mac, and the price was indeed $2,495. "Today, one year after Lisa, we are introducing the third industry milestone product: Macintosh," he told the audience, the other two machines being Apple II and the IBM PC.

With Vangelis' musical score from *Chariots of Fire* playing, he pulled out the Macintosh, demonstrated its voice synthesis and the rest became history. For this was a machine that appeared to have it all. There was some amazing software such as MacPaint, among the first WYSIWYG art packages, and MacWrite, a WYSIWYG word processor. Together these applications set a bar for other packages to follow. It showed the Macintosh was a creative machine with solid real-life uses.

Quite where Apple would be today without the Mac is anyone's guess. It's well known that Apple was in trouble in 1997 and that Bill Gates ended up pulling the company back

ABOVE Steve Jobs shows off the original Apple Macintosh in 1984
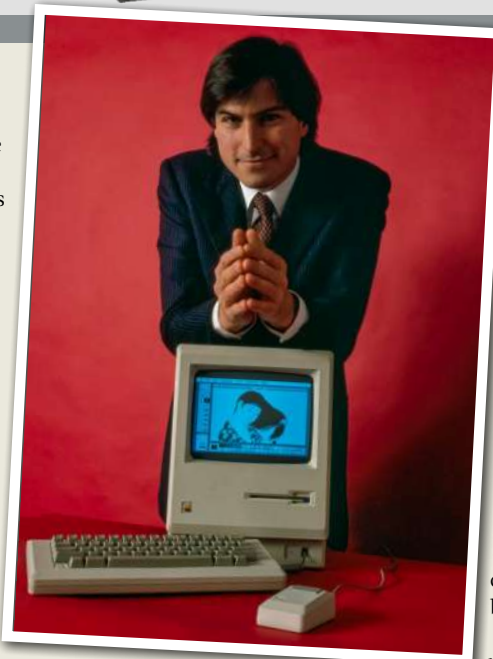
from the brink of bankruptcy.

At the same time, Apple has kept apace with technology. "The Mac has run on four different processor families over the years: the 60000, the PowerPC, Intel and then finally Apple Silicon," said Hertzfeld. "Apple flawlessly executed each of those major transitions, which could have killed the company if it had been botched."

Indeed, it was a rejuvenated Mac that kickstarted a journey that put Apple back on the right path (the attractive iMac G3 in 1998 was, once again, a consumer desktop product aimed at the masses). "The most impactful advance was the switch to Next-based software around 2000," Hertzfeld added. And the iPod, iPhone, iPad and Apple Watch would likely never have got off the ground if the Mac had failed.
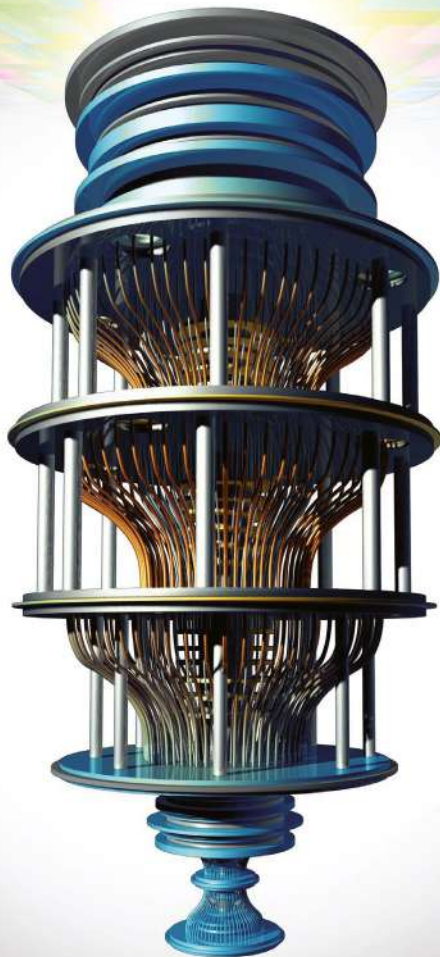
In many ways, the push for simplicity in Apple products today harks back to Ruskin's ethos: the strong belief that most people just want a computer that works when they turn it on – one that doesn't need to be messed around with internally in order to be upgraded or expanded. When Apple sticks to user-friendliness, it seems to do well. Belief in the way of the Mac seems to have Apple's back. ●

Quantum computing is here… with one small caveat

The government is backing 30 projects to kickstart quantum technologies, even though the hardware isn't ready. Nicole Kobie meets one company mitigating the effects of climate change to find out why

Quantum computers are only just edging into useful existence, but the world isn't willing to wait for the technology to mature. They're already being put to good use in finance, energy production and manufacturing – and soon, if all goes well, quantum systems will predict potential flood damage across the UK to help plan mitigations against the impacts of climate change.

Multiverse Computing is leading one of 30 projects backed by the UK government as part of efforts to develop quantum technologies for public sector applications. Alongside its partners, Oxford Quantum Circuits and Moody's Analytics, Multiverse is developing an algorithm to optimise neural network outputs for more detailed flood modelling.

This is part of the government's Quantum Catalyst Fund, a £15 million pot of cash to encourage quantum technologies to be developed for public use. Multiverse's project was handed a slice of that money for a three-month feasibility study as phase one of the fund, with contracts doled out for any promising ideas as part of phase two, in which they'll be asked to make a prototype or product demonstration.

That £15 million is just the start. The fund is part of a wider National Quantum Strategy published in March 2023 that will see £2.5 billion invested in the next ten years. The belief is that quantum technologies could offer solutions in healthcare and energy infrastructure. And – through quantum clocks and communications – it could help railways, emergency services and telcos step away from satellites to a more secure alternative.

But given quantum computers remain very much a work in progress, how can anything get done? Enter hybrid quantum computing.

■ What is quantum computing?

Let's step back to basics. Classical or traditional computers make use of on/off transistors, with data stored in bits that are either a one or a zero. Quantum computers differ by taking advantage of quirks of physics, in particular quantum superposition and entanglement. So a qubit – a quantum bit – can be on or off, but it can also be both; this is superposition. That means data can be processed in parallel. The second property is

we can make use of quantum ideas and more limited quantum hardware by combining it with classical algorithms and computers.

"A quantum algorithm is like a classical one but uses several phenomena that are quantum that you don't have in a classical computer," Gaspar said. "For example, entanglement and superposition… We are currently building machines that can make use of those effects."

To an extent, it follows the development pattern of traditional computing, Gaspar says. At first, algorithms ran sequentially on a single CPU; then a second CPU

entanglement, which means the state of a qubit can be related to another, and this enables advanced algorithms.

This means quantum computing could enable advanced modelling or maths that we can't do now. But there are challenges. Reading the state of a superposition qubit isn't really possible, so it drops back to a one or zero, meaning the final result requires further processing to unpick; that means more processing power is needed, not to mention software to do the work. Another challenge is decoherence: quantum computers interact with their environment, and that can disrupt data and calculations, corrupting results. Mitigating that requires complex error correction.

There's a further challenge: actually building a quantum computer. They do exist now, but with a limited number of qubits. The IBM Quantum One was the first such device to be made available for commercial use, but it only has 20 qubits. Back in 2019, Google claimed it had achieved quantum supremacy – performing a calculation that a supercomputer couldn't do on a human timescale – using its Sycamore device, which had 53 qubits. And in December 2023, IBM revealed its Condor quantum computer with more than 1,000 qubits.

We don't really know how many qubits are required to do the work we'd like quantum machines to do as it depends on the task, but thousands or even tens of thousands could be required for the applications being dreamed up. It also depends on the type of quantum computer, as there are different designs, from superconducting machines like those made by Google and IBM to photonic

designs. These use neutral atoms, trapped ions and quantum dots.

"Each of those architectures has several benefits and drawbacks, so right now it's not clear which of those architectures is going to be the one that scales," Victor Gaspar, head of business development at Multiverse, told *PC Pro*. (For this project, Multiverse Computing is working with Oxford Quantum Circuits, which uses a patented three-dimensional scalable design called a "coaxmon".)

Quantum computers aren't designed to take over from the laptop on your desk or the smartphone in your pocket. Instead, they're a specific tool that works well for some applications, be it maths problems,
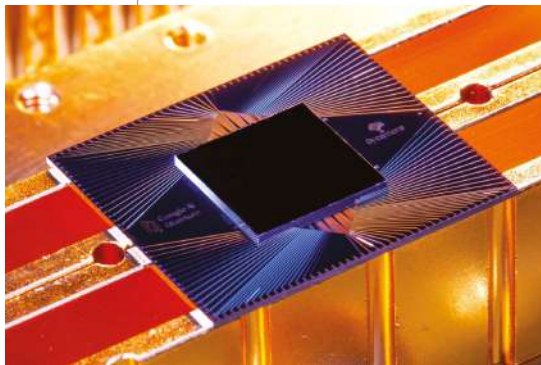
cryptography or simulations. Making use of quantum hardware requires algorithms written specifically for such computers – and that's part of the reason hybrid systems have appeal. We need to develop quantum computers and the software and algorithms to run on them in concert.

The key takeaway on all of this is that quantum computing isn't quite here yet and it's not easy to build.

■ Hybrid today
Though we as yet lack quantum computers at a practical level – they exist, but largely in labs, and not in the form required to do everyday work –
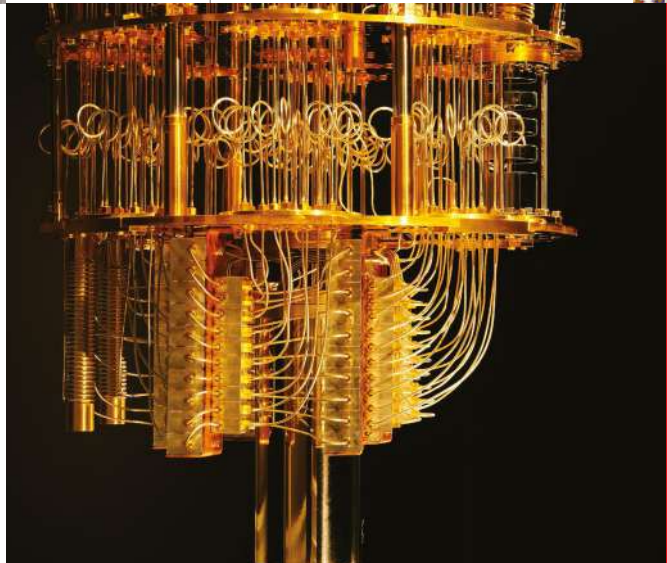
allowed for parallel computing. "Now we are developing a technology that has several properties that are not in classical [computers] that you can make use of for developing new algorithms," Gaspar said.

And that takes time, he notes – after all, many of the most famous algorithms in use today were developed in the 1980s, and we're still coming up with new ways to get the most out of classical computers. That's one reason why it makes sense to start developing software and algorithms for quantum computers when the hardware isn't quite ready yet, as it's going to take years or decades to really get to grips with these weird new machines.

Multiverse Computing has an algorithm that will work with the project in question, but one of the first steps will be to optimise it for the hardware being supplied by project partner Oxford Quantum Circuits.

■ Floods of data
This particular hybrid quantum project seeks to better model the

> **"A quantum algorithm is like a classical one but uses several phenomena that are quantum that you don't have in a classical computer"**

potential for flooding across the UK, especially as the climate crisis exacerbates the risks. The aim is to understand where and when to expect floods, and better predict their impact on surrounding areas, be it homes, transport networks or infrastructure. However, computational fluid dynamics are notoriously complicated, and the challenge is exacerbated by the need to pull in a lot of data to improve the accuracy and granularity of a model.

Multiverse Computing and its partners will use shallow water equations, a subset of computational fluid dynamics, to model bodies of water including rivers and the ocean. "In classical computers this has a really high computational cost for simulation, especially for large areas in a high resolution," said Gaspar. "If you want to model a huge mass of land that intertwines with a huge mass of water, and you want high resolution with buildings and coastal features and all that, it's highly complex."

For example, a modelling system could choose to ignore the impact of windows on flood effects, but a more detailed simulation might include windows. "We want to proceed in precise detail," Gaspar explained.

Multiverse Computing is going to help address that computational challenge by adding a quantum circuit into the neural network architecture to optimise the system and improve training performance while also reducing memory consumption. That will use Oxford Quantum Circuits' 32-bit quantum circuit.

The system will also be able to increase the expressivity of neural networks, which refers to how such a deep learning system approximates functions for better predictions. And, when more qubits are available, this system will be able to scale up to boost the neural network for better accuracy.

Practically, the neural network output feeds into the variational quantum circuit. That means the neural network must be designed in the right way for the output to match the quantum gates. That quantum circuit offers a result that is measured, and that measurement is then input back into the neural network.

"Essentially what we're trying to solve is an optimisation problem at the end of the day, to simulate the effects of these floods," said Sam Mugel, chief technology officer at Multiverse. "And for this optimisation problem, we're going to solve it on a quantum computer using these variational quantum algorithms."

The challenge is that the quantum computer is small, with just 32 qubits, but the problem is very large, with millions of variables. "The trick we're going to do is we're going to use a neural network architecture to compress the information," Mugel said. "We have input, we're going to compress it, run this on the QPU (the quantum computer), run the optimisation problem on the QPU, and then run it back through [the] neural network to decompress it."

There's plenty of work to do first. In the initial phase of government-funded work, Multiverse Computing is proving the project can succeed – it's effectively a feasibility study. That requires understanding the nature and structure of flood data and how it needs to be processed so it can be used to train the neural network, but also showing how the hardware and software will work together.

"What we want to show in phase one is that… larger quantum circuits will be able to solve problems that can't be solved with classical computing," Gaspar said. If approved by DEFRA for

> **"We need software to show what the hardware can do, but it's difficult to develop software when the hardware doesn't exist yet"**

Hybrid quantum computing and healthcare

Hybrid quantum computing could have a particularly big impact on healthcare, with Professor Katherine Royse stating at an IBM event that drug discovery, diagnosis and vaccine creation can all be made quicker through techniques available today.

Professor Royse, who is director of the Science and Technology Facilities Council's Hartree Centre, says this isn't theory. "For drug discovery, for example, we are finding that it is picking molecules better than a classic system would do," she said, referring to a mix of IBM's quantum computers, classical high-performance computing and AI.

Although she emphasised that all this work was still at the proof-of-concept stage, she added that hybrid quantum computing was also producing results in cancer diagnosis – detecting not only that cancer was present but what type of cancer it was, with a stunning 70% accuracy level.

"Next time we have something like a global pandemic like Covid we've already proved that using hybrid workflows would have come up with drugs that are potential treatment pathways more accurately than we did on the classic process. And that was a speed up compared to what we'd ever had before."

ABOVE Professor Katherine Royse (centre) believes hybrid quantum computing will help us tackle future pandemics

phase two, Multiverse Computing and its partners will shift to implementation and building a working prototype.

■ Long road ahead

So if a 32-qubit circuit isn't enough to run an entire algorithm, how many qubits do we need? Gaspar says we simply don't know, and nor do we know how long it will take to build large enough quantum computers.

It's a chicken and egg situation: we need software to show what the hardware can do, but it's difficult to develop software when the hardware doesn't exist yet. And that's why hybrid quantum makes sense: it lets us see the value of quantum computing now, expand our simulation and modelling without waiting for larger quantum machines, and allows us to start developing the associated technologies such as software and algorithms so we're ready to go when the hardware can be scaled up.

"If you think about it, the semiconductor industry has been around for 70 years," said Gaspar. "I'm not going to say quantum computers are going to take 70 years, but we need the technology to develop. And right now we are at the stage where we need to be clever in how to design those algorithms and do more hardware crossover designed to make the most out of these scarce resources."

Hybrid quantum means we can get some results now. But full quantum computing will first need serious technological breakthroughs – and serious cash. "Before we can justify that level of investment, we need to be able to say that we know when we arrive at this level, we'll be able to solve this type of problem better," said Mugel.

Like Gaspar, he points to the long history of chips. "The semiconductor industry has had trillions poured into it, but before we went ahead and poured all that money into it we first started with transistors," he said. "Applications with very, very few transistors showed that there was value. Once we showed the initial disruptive use case, from there we were able to justify all the investment. For us, I think this project is one of several where we really are seeking to show that for quantum computers."

In other words, this project isn't just about water flow simulation, though anyone living in an area prone to floods will welcome better predictions. Instead, it's a way to test if quantum computing is worth all the effort – and to spark investment in a technology that could be the next revolution in computing. ●

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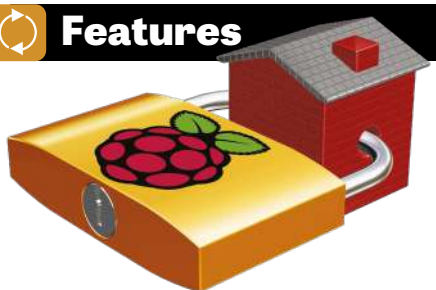# Next month

ON SALE
8 February 2024

Features

CES 2024
The team select their highlights from the world's biggest tech show, giving a taster of the technological treats in store this year.

Features

Secure your house with a Pi
We reveal how, with a variety of Raspberry Pis, some inexpensive add-ons and your wireless home network, you can design a security system that exactly meets your needs.

Features

Deep dive: Windows Defender
We dig into the power-user features that let you take full control of your protection, and ask if there's still a place for third-party security.

Labs

Linux distros
The untimely demise of Windows 10 is pushing many people to try Linux, and we say: don't be afraid. There are some fantastic distros to choose from, and our Labs tests reveals their strengths and weaknesses.
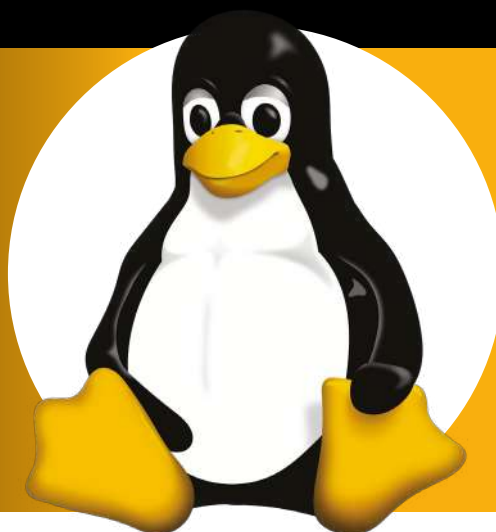
Retro

Grand Theft Auto's impact
The *Grand Theft Auto* franchise powers onwards. We examine how the game caught fire to become so influential (and even a theme for Barry's podcast pics, as discussed on p33).

The Network

Network monitoring software
Software that makes it easier than ever to fix bottlenecks, anticipate problems and spot hackers. Dave Mitchell explains all.

Futures

Tech will save your broadband
Nicole discovers how Openreach is using futuristic technology such as drones, AI and VR to fix our connections.

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Old thinking, old production methods and old tech won't wash in 2024, says Jon Honeyball

Here's a scenario that may sound familiar. An industry in turmoil due to a Big Change, with the market rapidly switching to new technology. Small, nippy companies native to this new tech are emerging while the big players are acting like dinosaurs in their slow, clumsy attempts to adapt to a new business reality.

For once, I'm not talking about IT. I'm talking about cars. The shift to electric is happening in real-time, and the vendors are struggling.

Things are so bad that, a few months ago, Volkswagen started a three-year cost-cutting programme designed to save €10bn. CEO Thomas Schäfer told managers that "the roof is on fire". Just before Christmas, HR board member Gunnar Kilian said: "We need to finally be brave and honest enough to throw things overboard that are being duplicated within the company or are simply ballast we don't need for good results".

I am far from surprised. The legacy auto manufacturers have so far done a bad job of adjusting to the new reality. For example, VW's new Golf can be had for £26,705, while its electric offering, the ID3, starts at £37,255.

Worse, they have tried to add hybrid capabilities to existing platforms. Like switching from CRT to LCD but with the same casing. And these companies' new electric offerings (including the ID3) have been beset with an ongoing firestorm of software issues.

At the cheaper end of the scale, a slew of new Chinese cars are arriving in the market at prices that European auto makers can't compete with. Whether this has been made possible by Chinese government handouts is an exercise for the reader. But just remember that European car manufacturers are not averse to a little financial tickle. Or a very large one.

Then there's Elon Musk. Put aside your personal feelings about the man, and it's clear that Tesla has had a vision of design and deployment that's left everyone else in the dust. Build quality might not always be brilliant, but Tesla had the guts to do something profoundly new. Just like Apple introducing the iPhone, or betting the farm on the move from Intel to ARM.

There are even bigger questions to answer about infrastructure. Where is the VW (or BMW or JLR) equivalent to the Tesla Supercharger network? It was always clear that the global oil companies wouldn't rush chargers into petrol stations, and who wants to use one of the slower chargers? If they're even working.

To see how far behind the car manufacturers are, just look at the Tesla Cybertruck. Ignore the *Thunderbirds* styling and look instead at the engineering. It's a fully 800V power train: this isn't unique, with Porsche, part of Volkswagen Group, launching this in the Taycan back in 2019, but the internal wiring is. Tesla has moved away from the ancient 12V power system with slow CANBUS interconnects and moved to 48V and Ethernet. Quadruple the voltage and you quarter the current. Drop the current and you can use lighter and cheaper wires. And the resistive losses are commensurately lower, too.

While the Cybertruck won't be coming to these shores, its 48V Ethernet system, its forgings and castings, and the radical new production methods that Tesla is rolling out, will help the company offer the forthcoming Model 2 at a low price. And still make a lot of money.

You can't do this if you have a huge production structure based around 12V. Don't forget that Volkswagen Group is just the top of the pyramid: there are thousands of component suppliers working to the 12V standard, all of whom feed into the mother company.

Rather than tackle the problem, the big manufacturers have retreated into a hole of backward thinking, poor implementation and some dreadful UI, software development and business decisions. Anyone want to pay BMW a monthly subscription to enable the heated steering wheel in its new car? No, I thought not.

Ask your car dealer whether your proposed new vehicle can do full over-the-air updating of all systems and processors. Watch their faces whiten, suggesting instead that bringing your car in to be plugged into

> ❝ Rather than tackle the problem, the big manufacturers have retreated into a hole of backward thinking, poor implementation and some dreadful decisions ❞

the garage computer is a much wiser answer. Now tell them to join the 21st century and leave the showroom.

The next few years are going to be rough for BMW, Volkswagen and others, akin to the switch from chunky mobiles to smartphones. Remember how Apple ended up with all the profit for the sector, almost wiping out incumbent Nokia in the process? The same will happen in electric cars. Tesla has done an Apple on the European car industry. China is doing a Samsung.

If this analogy doesn't compute with the car makers, let's try another: fossil fuels are called fossil for a reason. Lazy-thinking dinosaurs are destined to die.

▪ Jon Honeyball is contributing editor of *PC Pro*. He's still running a ten-year-old Audi with 100,000 miles on the clock. And will do so until it drops. Email jon@jonhoneyball.com

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